JOÃO PAULO NASCIMENTO DA SILVA

DISRUPTIVE INNOVATION AND ECOSYSTEMS: THE CASE OF EVTOLS

LAVRAS – MG

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

Prof. Dr. André Grützmann

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INOVAÇÕES DISRUPTIVAS E ECOSSISTEMAS: O CASO DOS EVTOLS

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"I will say of the Lord, "He is my refuge and my fortress, my God, in whom I trust"

(Psalm 90:2)

"Looking is the nature of wisdom"

(Rick Riordan)

"Si vis pacem, para bellum"

(Publius Flavius Vegetius Renatus)

"They did not know it was impossible, so they did it"

(Jean Cocteau).

RESUMO GERAL

Mudanças tecnológicas sempre proporcionaram profundas mudanças econômicas e sociais, onde o mercado de mobilidade sempre representou um importante ecossistema tecnológico e de negócios. O ecossistema de transporte atual é conduzido por empresas de produção de veículos movidos a combustão e as atuais pressões ambientais, sociais e econômicas tem forçado a reinvenção dessas tecnologias. Os problemas atuais do mercado são uma oportunidade para que uma disrupção possa mudar todo o padrão de inovação e negócios existente. Os Electric Vertical Take-Off and Landing, ou eVTOLs, são veículos que combinam propulsão vertical com baterias elétricas de longa duração e mecanismos de automação, comunicação e navegação de controle de voo para que o transporte passe da dimensão terrestre para a aérea. Com o advento dessas novas tecnologias surge o mercado de Mobilidade Aérea Avançada (AAM), que pode trazer um impacto para o ecossistema existente e representar um salto no mercado. Considerando que as inovações disruptivas como tecnologias e modelos de negócios que afetam o padrão dentro de um ecossistema existente, os eVTOLs são uma tecnologia com potencial para criar um novo ecossistema de inovação disruptiva. Tal contexto é útil para investigar transformação tecnológica atual com base no impacto de novas tecnologias na disrupção de indústrias estabelecidas e na evolução dos ecossistemas. Assim, é necessário compreender a estruturação desse novo ecossistema frente a essa disrupção. Com base nestes preceitos, esta Tese de Doutorado tem por objetivo "investigar se a inserção da inovação potencialmente disruptiva dos eVTOLs pode impactar o ecossistema de transporte e mobilidade". Este estudo apresenta carácter qualitativo, descritivo, exploratório e preditivo, onde busca compreender a inserção de uma tecnologia em desenvolvimento no atual ecossistema. Os resultados apontam que o processo de disrupção tem um potencial impacto de evoluir ecossistemas, com características dos atores e tecnologias existentes e novos, e que vão crescer e se desenvolver em torno da disrupção (Artigo 1). A chegada das novas tecnologias de eletrificação, automação e dos eVTOLs tem impactado empresas de diversos setores em busca de uma mobilidade mais sustentáveis (Artigo 2). Este impacto apresenta resultados positivos na redução do consumo, de emissões e ganhos financeiros, sendo oportunidades para saltos de desenvolvimento tecnológicos (Artigo 3). Essas potenciais disrupções estão reestruturando toda a cadeia e a proposta de valor, abrindo espaço para atores de diversos setores na evolução desse novo ecossistema (Artigo 4). Por último, os cenários apontam para a possível disrupção dos eVTOLs na evolução dos mercados de mobilidade aérea, onde o conjunto de tecnologias necessárias e a reestruturação da cadeia de valor são uma disrupção no ecossistema de inovação, e onde a proposta de valor diferenciada das tecnologias de mobilidade existentes transforma o ecossistema de negócios e abre espaço para o novo mercado (Artigo 5). Dessa forma, esta Tese defende que o impacto da disrupção dos eVTOLs está abrindo uma oportunidade para evolução do ecossistema de inovação de mobilidade, coevoluindo com atores e tecnologias, alterando a proposta de valor do ecossistema existente, e abrindo oportunidade para criação do novo mercado de AAM.

Palavras-chave: Inovação Disruptiva; Ecossistema de Inovação; Ecossistemas Disruptivos; Modelo de Negócios; eVTOL; Mobilidade Aérea Avançada – AAM.

ABSTRACT

Technological changes have always provided profound economic and social changes, where the transportation mobility market has always represented a significant technological and business ecosystem. Combustion-powered motor vehicle production companies drive the current mobility ecosystem, and environmental, social and economic pressures have forced the reinvention of these technologies. The current market problems are an opportunity for disruption to change the entire innovation and business pattern of the existing ecosystem. Electric Vertical Take-Off and Landing, or eVTOLs, are vehicles that combine vertical propulsion with long-lasting electric batteries and mechanisms for automation, communication and flight control navigation to create the possibility of transport moving from the land dimension to the air, facilitating transportation mobility. With the advent of these new technologies, the Advanced Air Mobility (AAM) market emerges, which can impact the existing ecosystem and represent a leap in the market. Considering disruptive innovations as technologies and business models that affect the pattern within an existing ecosystem, eVTOLs are a technology with the potential to create a new disruptive innovation ecosystem. Such a context helps investigate current technological transformations based on the impact of new technologies on the disruption of established industries and the evolution of ecosystems. Thus, it is necessary to understand the structure of this new ecosystem in the face of this disruption. Based on these precepts, this Doctoral Thesis aims “to investigate whether the insertion of the potentially disruptive innovation of eVTOLs can impact the transportation mobility ecosystem”. This study is qualitative, descriptive, exploratory and predictive, and it seeks to understand the insertion of technology under development in the current ecosystem. The results point out that the disruption process potentially impacts evolving ecosystems, with characteristics of existing and new actors and technologies that will grow and develop around the disruption (Article 1). The arrival of new technologies for electrification, automation and eVTOLs has impacted companies from different sectors in search of more sustainable mobility (Article 2). This impact presents positive results in reducing consumption, emissions and financial gains, as opportunities for technological development leaps for countries (Article 3). These potential disruptions are restructuring the entire chain and the value proposition based on the development of disruptions, opening space for actors from different sectors in the evolution of this new ecosystem (Article 4). Finally, the scenarios point to the possible disruption of eVTOLs in the evolution of AAM markets. A set of necessary technologies and the restructuring of the value chain are a disruption in the innovation ecosystem, where the differentiated value proposition of the existing transportation mobility technologies transform the business ecosystem and opens space for the new market (Article 5). Thus, this Thesis argues that the impact of the disruption of eVTOLs is opening an opportunity for the evolution of the transportation mobility innovation ecosystem, co-evolving with actors and technologies, changing the value proposition of the existing ecosystem, and opening an opportunity for the creation of a new market from AAM.

Keywords: Disruptive Innovation; Innovation Ecosystem; Disruptive Ecosystems; Business model; eVTOL; Advanced Air Mobility – AAM.

SUMÁRIO

FIRST PART - GENERAL INTRODUCTION

"Only those who have given up on living think that dreams are impossible"

(Masami Kurumada – Hyoga).

1. INTRODUCTION

The present study addresses the creation of a new Ecosystem in the face of a possible Disruption of the transportation mobility market. The introductory section is composed of the contextualization and motivation of the study, presenting problematization, objectives, and justifications. It ends with the structure of this study.

1.1. Contextualization of Research and Motivation

Technological advances have always triggered profound economic and social changes. Such contexts help understand current technological transformation when investigating the impact of new technologies on disrupting established industries (CLARKE, 2019; SANDSTRÖM, 2016). From historical transformations such as hydraulic power, steam power, and chemical industry, to the most used technologies today such as combustion engines, electricity, electronics, hardware, and software, and even technologies that are currently being developed such as automation, robotics, digitization, big data, internet of things, cloud computing and artificial intelligence. The world lives in an era of continuous upheavals of technological and business model innovations that disrupt and reorder how companies and their ecosystems operate (KUMARASWAMY; GARUD; ANSARI, 2018). Technological changes are forces that can alter an entire industry's competitive pattern and structure (SANDSTRÖM, 2016; SCHUMPETER, 1942).

Few products had such a profound influence on the way of life as transport vehicles. The development of transportation mobility technologies, such as cars, motorcycles, buses, and trucks, allowed the growth of cities and transformed the way of thinking about freedom, lifestyle, work, shopping, and leisure. However, they have also been the source of many environmental, economic, and social externalities. The main ones being congestion, atmospheric pollution, excessive noise, accidents, inefficient use of resources, poor infrastructure, maintenance and management costs, and reduction in well-being in cities (AMIOLEMEN; OLOGEH; OGIDAN, 2012; CONSTANTINESCU; FRONE, 2014; FAGNANT; KOCKELMAN, 2014). Vast sums of money have been spent on incremental improvements in technologies and infrastructure, but problems still need to be solved (WILLIAMS, 2014).

Williams (2014) described the externalities caused by motor vehicles as "wicked problems", which are complex and challenging, if not impossible, to solve. Due to the complex interdependencies involved, it is necessary to seek a multidisciplinary and a holistic innovation perspective to find solutions. In this sense, the ecosystem theory provides a framework that can help conceptualize the problem (ADNER, 2017; HOU; SHI, 2020; MOORE, 1993), and the disruptive innovations approach can bring possible solutions and offer new opportunities (CHRISTENSEN et al., 2018; DEDEHAYIR; ORTT; SEPPÄNEN, 2017; LIU et al., 2020; PETZOLD; LANDINEZ; BAAKEN, 2019).

The term technology means the processes by which an organization transforms work, capital, materials, and information into products or services with the capacity to bring about an improvement in the trajectory of performance of great value in the market, while the term innovation refers to the changes of this technology (CHRISTENSEN, 1997; CHRISTENSEN; BOWER, 1996). According to Granstrand and Holgersson (2020), innovation results from a process with two main features, the novelty of a change and the usefulness or success of applying something new. For the authors, technology is a component of innovation, not innovation itself.

According to the Oslo Manual (2018), an innovation is a new or improved product or process (or a combination thereof) that differs significantly from previously existing products or processes. It can affect individuals, institutions, economic sectors, and entire countries in various ways. In this sense, while incremental innovations will continuously fill the market change process, the most radical (or disruptive) innovations can cause significant changes in the world. In this way, disruption can significantly impact a market and the economic activity of companies in that market. The impact can, for example, change the structure of a market, create a new market or make existing products completely obsolete (CHRISTENSEN, 1997; OECD, 2018).

The theory of disruptive technologies explores how innovations with a different set of characteristics and a different value proposition have outperformed dominant technologies in the market (BOWER; CHRISTENSEN, 1995; CHRISTENSEN, 1997; CHRISTENSEN et al., 2018). These technologies become disruptive innovations caused by changes in technology and business models to create a new value proposition for the market (CHRISTENSEN, 2006; PETZOLD; LANDINEZ; BAAKEN, 2019). Business models for disruptive innovations are strategic architectures that redefine the meaning, creation, and capture of value (COZZOLINO; VERONA; ROTHAERMEL, 2018; TEECE, 2010). When disruptive technologies emerge in the market, disruptive business models are introduced to exploit the new technology (COZZOLINO; VERONA; ROTHAERMEL, 2018).

In turn, an ecosystem is a collaborative arrangement where companies jointly create value for their customers that they could not create in isolation (ADNER, 2006). Ecosystems operate through constantly evolving actors, activities and artefacts, institutions and relationships (BELTAGUI; ROSLI; CANDI, 2020). An innovation ecosystem, the focus of this study, is based on the development of technology (ANSARI; GARUD; KUMARASWAMY, 2016; SANDSTRÖM, 2016) and emphasizes collaboration, complementarity and competition between actors around technological artefacts (GRANSTRAND; HOLGERSSON, 2020; HOLGERSSON et al., 2022). In the ecosystem, the development of a market and an economy around innovation occurs, operated by business models that sew the value network in a co-evolutionary dynamic of permanent exchange with environments for continuous innovation (HOU; SHI, 2020; MA et al., 2018; PUSHPANANTHAN; ELMQUIST, 2022).

On the other hand, the business ecosystem represents an environment in which the company must monitor and react (LI, 2018), to adapt to the development of emerging technologies and business ideas (ADNER; KAPOOR, 2010). There is a shift from the focus on competition in the business ecosystem to the focus on collaboration and value creation in the innovation ecosystem (GOMES et al., 2018; GRANSTRAND; HOLGERSSON, 2020). In this sense, new technologies and market disruptions are important phenomena that can impact existing markets, innovation, and business ecosystems (DEDEHAYIR; ORTT; SEPPÄNEN, 2017; PALMIÉ et al., 2019).

As disruptive innovations are usually developed and commercialized in ecosystems rather than isolated companies, the themes of disruptive innovation and innovation ecosystem intersect (PALMIÉ et al., 2019). Business models design the prospect of inserting disruption within the innovation ecosystem and become an essential tool for the demand for the co-evolution of business strategies (HOLGERSSON et al., 2022; KUMARASWAMY; GARUD; ANSARI, 2018; PUSHPANANTHAN; ELMQUIST, 2022; RABIN; KALMAN; KALZ, 2020; THOMAS; AUTIO; GANN, 2022).

Disruptions usually do not comply with regulatory norms, technological standards, and existing infrastructure. Therefore, they can affect the entire value structure of an ecosystem (CHAN; FUNG, 2016). To this end, the value proposition of the disruption business model can lead to competition in the core market, or it can create a new market and, consecutively, a new ecosystem. In this way, companies are linked to an ecology of value and must align their strategies for the ecosystem success (BERS et al., 2012; MOORE, 1993; ZALAN; TOUFAILY, 2017) and its disruption (DEDEHAYIR; ORTT; SEPPÄNEN, 2017; OGHAZI et al., 2022).

Thus, the academic literature needs to provide a clear picture of the impact of disruptive innovation on the ecosystem. Only a few studies have sought to understand how existing ecosystems are affected by disruptive innovations – thus, however, knowledge of how disruptive innovations can disrupt existing industries and constitute new ecosystems remains limited

(ANSARI; GARUD; KUMARASWAMY, 2016; OGHAZI et al., 2022; OZALP; CENNAMO; GAWER, 2018). When a disruptive innovation drives a rapid change in the environment, one should not neglect the power of the forces that build and transform ecosystems (KUMARASWAMY; GARUD; ANSARI, 2018; PALMIÉ et al., 2019). Thus, understanding the potential of disruptive innovations to disrupt the configuration of an ecosystem is a research gap to be investigated (CHRISTENSEN et al., 2018; OGHAZI et al., 2022; PALMIÉ et al., 2019).

Such a gap is further related to the fact that the actors of the disruption can reinforce the connections with the ecosystem, making the existing actors both part and drivers of the disruption. However, the value model of the new ecosystem arising from the disruption will be inherently different from that of the existing innovation ecosystem. This reconfiguration understands that the advent of disruption will essentially change the existing value model, resulting in changes in the connections between existing and new companies and ecosystems (ADNER, 2017; DEDEHAYIR; ORTT; SEPPÄNEN, 2017).

Among the solutions resulting from ecosystem disruptions, technologies were in several fields, such as the transport ecosystem. The current configuration of the transport system searches for faster, more convenient, safer, more economical, and more sustainable transport, characteristics that current transport products cannot meet (LIU et al., 2020; WILLIAMS, 2014). The current transportation mobility ecosystem is driven by Internal Combustion Engines (ICE) production companies (YAN; TSENG; LU, 2018). The costs of fossil fuels and the environmental results from this type of power source are variables that force the reinvention of current modes of transport. The incompatibility of these ecosystems and current transport technologies leads to a rethink, with a broader view of the problem, the proposal of a transportation mobility system that reduces environmental, economic, and social impacts (WILLIAMS, 2014).

Unsatisfied needs and current market problems that cannot be fixed based on existing technologies are opportunities for a shift in the market. A technology and business model disruption could change the entire innovation and business pattern of the existing ecosystem. The insertion of more sustainable vehicle technology powered by electricity (Electric Vehicles – EVs), or with autonomous technologies (Autonomous Vehicles – AVs), for example, can cause disruption (DIJK; WELLS; KEMP, 2016; SKEETE, 2018). Vehicle electrification is already available in developed and some developing countries, while automation is an important technology that is still in the testing phase (GARTNER, 2015, 2018).

Even with the impacts of vehicle electrification and automation still incipient, Electric Vertical Take-Off and Landing, or simply eVTOLs, are vehicles that combine vertical propulsion with long-lasting electric batteries and mechanisms for automation, communication and flight control navigation (UBER ELEVATE, 2016). EVTOLs allow transport to move from the land to the air dimension, facilitating transport (CURTIS, 2019; GARROW; GERMAN; LEONARD, 2021; PRADEEP; WEI, 2019; PUKHOVA et al., 2021). With the advent of new electrification, automation and air transport technologies, a new industry emerges, Advanced Air Mobility (AAM), representing a new leap in transforming mobility reality. As part of a larger picture, while the urban air mobility (UAM) is a subset of AAM and focuses on urban areas, the AAM focuses on the development of an entire industry and emerging markets for eVTOLs for passenger and freight transport (COHEN; SHAHEEN; FARRAR, 2021; NASA, 2020; REICH; COHEN; FERNANDO, 2021; US DEPARTMENT OF TRANSPORTATION, 2022). To this end, this Thesis will refer to AAM encompassing both concepts as part of the transportation mobility ecosystem.

A new ecosystem, based on a new class of aircraft with a focus on on-demand air mobility, can transform the transportation experience, where "air and ground transportation solutions will create a network of transportation mobility that will enable people and goods to flow in a seamless, affordable way" (EMBRAERX, 2020, p. 4). The all-electric and autonomous eVTOLs are a possible solution to congestion and automation problems on land roads, where the airspace is highly controlled, and there are fewer variables, such as humans (COHEN; SHAHEEN; FARRAR, 2021; GARTNER, 2019; REICH; COHEN; FERNANDO, 2021; TANG et al., 2021). EVTOLs would allow a promising concept for users and governments regarding infrastructure, management, legislation, security, pollutant emission costs, cargo transportation, passengers, and user autonomy (COHEN; SHAHEEN; FARRAR, 2021; GARROW; GERMAN; LEONARD, 2021; UBER ELEVATE, 2016; VIEIRA; SILVA; BRAVO, 2019). This new technology can create a new transport air market and potentially impact the entire business model structure of the existing transportation mobility market.

With eVTOL technology, new ways to deliver goods and services faster, more efficiently, flexibly, accessible, sustainable, and fully on-demand transport routes can bring new solutions (EMBRAERX, 2020; UBER ELEVATE, 2016). With the possible arrival of eVTOLs, some concerns are considerable, such as certification and regulation processes, new traffic control rules, cybersecurity issues, structural changes in transport infrastructure for eVTOL landing and takeoff, visual pollution of airspace, possible risks to biodiversity, among others (COHEN; SHAHEEN; FARRAR, 2021; GARROW; GERMAN; LEONARD, 2021; NASA, 2018; PRADEEP; WEI, 2019). Management solutions to these issues will only emerge through collaboration across the entire ecosystem.

Several companies are developing the eVTOL technology to make it a reality (AIRBUS, 2018; BELL FLIGHT, 2018; EMBRAER, 2021a; EMBRAERX, 2020; GARROW; GERMAN;

LEONARD, 2021; PRADEEP; WEI, 2019; UBER ELEVATE, 2016; VOLOCOPTER, 2019). The first models are being sold based on contractual commitments for aircraft supply. American Airlines and Virgin Atlantic announced the purchase of 400 eVTOL models from Vertical Aerospace to start exploring the AAM market (VIRGIN ATLANTIC, 2021). EVE, Embraer's subsidiary for the development of the AAM ecosystem, announced the negotiation of 200 eVTOLs with Halo Aviation to develop AAM services in the USA and England. EVE entered into partnerships with Ascent Flights to accelerate the AAM market in Asia and the Pacific, with Skyport to operate vertiports (vertical landing and takeoff points) in Asia and America, and with Helisul to create AAM services in Brazil (EMBRAER, 2021b, 2021a, 2021c, 2021d). So, there are innovative companies that are helping to shape the products, services, and infrastructure for this market.

According to the disruption characteristics in the literature, eVTOLs can be a potential market disruption (COHEN; SHAHEEN; FARRAR, 2021; REICH; COHEN; FERNANDO, 2021). In the interpretation of Bers et al. (2012), disruptions involve an unplanned technological advance that incremental improvements cannot achieve of an existing technology, which can interrupt entire industries and requires a deep and complex ecology of global actors. This process is taking place with eVTOLs because they do not adapt to the technologies and standards of infrastructure and support of the existing transportation mobility industry, because they are building an ecosystem with different global actors and technology, and because they are pioneering a new AAM market (DELOITTE, 2022). For Nagy et al. (2016) disruptions are a radical functionality to perform a new task that was impossible before the innovation and that innovates in creating a new demand and a new market. In this sense, the ability of eVTOLs to carry out short-term trips through the air, autonomously, quickly, sustainably, at an affordable cost, and on-demand are ways of creating a new demand for this mobility-as-a-service service and of creating a new market (LUFTHANSA INNOVATION HUB, 2021; PWC, 2021). Nagy et al. (2016) also point out that disruptions are innovations that use new materials or processes to create existing technologies and change the patterns of innovation ownership. Thus, eVTOLs are a technology that presents new materials and the production of electric, autonomous, aerial, and sustainable technology, in addition to presenting the change in the ownership of transportation mobility innovation with space for the ICE, aerospace, and technological industries, among others (DELOITTE, 2019; ROLAND BERGER, 2018).

To Si et al. (2020), disruption is a process with technological trajectories that differ from existing technologies. This fact is also related to eVTOLs, where the development trajectory is different in technological, legal, infrastructure, and benefit standards compared to current technologies (LUFTHANSA INNOVATION HUB, 2021). For Liu et al. (2020), disruptions are an opportunity to understand the market's dynamic process of long-term co-evolution. Being incipient technologies, eVTOLs and the AAM market are an opportunity to understand this dynamic process of co-evolution of disruption in different market scenarios (LUFTHANSA INNOVATION HUB, 2021; ROLAND BERGER, 2018). Finally, Christensen (2006) shows that organizations must be aware of products, technologies, or innovations under development or initial commercialization that may threaten the main market, developing a strategy to respond to a possible disruption that is in progress. For eVTOLs in the development stage, the predictive model aims to contribute ex-ante to the environment and prepare for the impact of a disruption (DELOITTE, 2022; KPMG, 2022).

Thus, considering that disruptive innovations such as technologies and business models that affect the pattern within an existing ecosystem (DEDEHAYIR; ORTT; SEPPÄNEN, 2017; PALMIÉ et al., 2019; PUSHPANANTHAN; ELMQUIST, 2022), eVTOLs are a technology with the potential to create a new disruptive AAM ecosystem. According to Christensen et al. (2018), disruptions can create a new market with a technological performance gap and an unmet business model. In this way, as eVTOLs are technologies that are emerging in search of creating a new market and using a new technological standard for air and terrestrial transport, this is configured as an insertion of technology and a potentially disruptive business model. As pointed out by Palmié et al. (2019), disruptive innovation ecosystems are ecosystems that develop and grow around a disruption. This way, the new AAM ecosystem is developed around the eVTOLs technology. So far, a potentially disruptive technology has been developed and tends to become a disruptive innovation as business models for the new market emerge and differentiate themselves from existing standards.

Therefore, as disruptive innovations usually have greater potential to disrupt the configuration of an existing ecosystem (CHRISTENSEN; RAYNOR; MCDONALD, 2015), it is expected that this effect can happen with the technology of eVTOLs. Moreover, as disruptive innovation ecosystems are ecosystems that develop a disruptive innovation and subsequently grow around that innovation (PALMIÉ et al., 2019), it is also expected the same effect in the AAM ecosystem. Considering the development of an innovation and highlighting the value of disruption in the context of the ecosystem (DEDEHAYIR; ORTT; SEPPÄNEN, 2017; HOLGERSSON et al., 2022; PALMIÉ et al., 2019; YAGHMAIE; VANHAVERBEKE, 2019), the potential disruption of eVTOL technology is an opportunity to a revolution in the future transport ecosystem provided by eVTOLs (CHRISTENSEN et al., 2018; COHEN; SHAHEEN; FARRAR, 2021; DEDEHAYIR; ORTT; SEPPÄNEN, 2017; OGHAZI et al., 2022; PALMIÉ et al., 2019; REICH; COHEN; FERNANDO, 2021).

1.2. Question Problem, Objectives and Justifications

The central Thesis of this research is that when a disruptive innovation occurs (CHRISTENSEN et al., 2018) in an existing ecosystem (ADNER, 2017; GRANSTRAND; HOLGERSSON, 2020; MOORE, 1993), it can suffer the effect of creative destruction (DEDEHAYIR; ORTT; SEPPÄNEN, 2017; NICOLAÏ; FAUCHEUX, 2015). Even though it is still in the process of disruption, it can shake an existing ecosystem (GRANSTRAND; HOLGERSSON, 2020), evolving the innovation ecosystem around the disruption and emerging a new market (business ecosystem) based on new technology, which requires the configuration of a new business model (DEDEHAYIR; ORTT; SEPPÄNEN, 2017; HOLGERSSON et al., 2022; OGHAZI et al., 2022; PALMIÉ et al., 2019).

In this case, the theory of disruption caused by new technologies can help to understand the restructuring of the value proposition and predict the disturbance in an ecosystem (CHRISTENSEN, 2006). As the studies of disruptive ecosystems are still limited, it is necessary to understand how the disruptive innovation ecosystems develop disruptive innovations and subsequently grow around this innovation (ANSARI; GARUD; KUMARASWAMY, 2016; DEDEHAYIR; ORTT; SEPPÄNEN, 2017; KUMARASWAMY; GARUD; ANSARI, 2018; OGHAZI et al., 2022; OZALP; CENNAMO; GAWER, 2018; PALMIÉ et al., 2019).

This new configuration results in a new value proposition through a holistic perspective of the disrupted ecosystem (DEDEHAYIR; ORTT; SEPPÄNEN, 2017; JACOBIDES; CENNAMO; GAWER, 2018). Within the perspective of the “wicked problems” of the current transportation mobility ecosystem (WILLIAMS, 2014), eVTOLs emerge to help search for a solution and offer new opportunities. As an innovation emerges within the market, it is necessary to understand the restructuring and evolution of the ecosystem (PUSHPANANTHAN; ELMQUIST, 2022; YAGHMAIE; VANHAVERBEKE, 2019). In this case, it is also necessary to deepen the potential disruption of this transportation mobility ecosystem provided by eVTOLs, that studies or future research agendas have not yet pointed out (CHRISTENSEN et al., 2018; COHEN; SHAHEEN; FARRAR, 2021; DEDEHAYIR; ORTT; SEPPÄNEN, 2017; OGHAZI et al., 2022; PALMIÉ et al., 2019; REICH; COHEN; FERNANDO, 2021).

In this way, the technology of eVTOLs is an essential tool in the construction of a new design of transportation mobility, and it is important to study the disruption of this technology in the possible AAM ecosystem. In this sense, to understand the effect of inserting a potentially disruptive innovation in an ecosystem, it is necessary to understand the following:

- **What is the impact of inserting the potentially disruptive innovation of eVTOLs on the transportation mobility ecosystem?**

To answer this question, this thesis will use the development of eVTOL technology and the AAM market as research objects. Specifically, this study aims to present the technological and strategic changes of the current ecosystem (focused on ICE technologies) in the face of disruptions (innovation ecosystem) of the AAM market and the co-evolution of the disrupted ecosystem (business ecosystem). Given the aforementioned, the objective of this thesis is:

- **To investigate whether the insertion of the potentially disruptive innovation of eVTOLs can impact the transportation mobility ecosystem.**

To achieve this objective, this thesis is subdivided into the following specific objectives:

1. To investigate how disruptive innovation can affect established industries and trigger the development of a new innovation ecosystem.
2. To analyze how potentially disruptive innovations can change the current technological transportation mobility ecosystem focusing on a sustainable perspective.
3. To analyze the technological, economic, and environmental impacts of the potentially disruptive innovations in the transportation mobility market.
4. To explore the value proposition dynamics evolution of potentially disruptive innovations in the transportation mobility ecosystem.
5. To identify and to analyze the possible scenarios for the potentially disruptive innovations of eVTOLs and the advanced air mobility ecosystem.

To provide the answers to the specific objectives, they have been divided into five articles. The first study proposes a systematic review to understand the combination of theories of Disruptive Innovation and Innovation Ecosystems since this relationship as a field of research is innovative (DEDEHAYIR; ORTT; SEPPÄNEN, 2017; OGHAZI et al., 2022; PALMIÉ et al., 2019). The work presents a theoretical model for the Evolution of Disruptive Ecosystems based on an ecosystem that is born and develops around a disruption.

The second article seeks to understand and present the change in the transportation mobility market ecosystem towards more sustainable, autonomous and aerial technologies. Therefore, as a methodological strategy, we seek to analyze organizations' missions, visions and values in the face of this technological paradigm shift and present the transition of the value proposition about new transportation mobility technologies (GUPTA; VEGELIN, 2016; KASTRINOS; WEBER, 2020). The third article 3 presents a comparative analysis of transportation technologies in the specific contexts of the BRICS and G7 markets. The article discusses the possible technological, economic, and environmental leap caused by replacing the current fleet of combustion vehicles with more sustainable technologies, autonomous and aerial (AMANKWAH-AMOAH, 2015; DIJK; WELLS; KEMP, 2016; JORDÃO, 2022).

The fourth study uses the Disruptive Ecosystem Evolution model proposed in Article 1 and the direction towards more sustainable, autonomous, and aerial technologies proposed in Article 2 to conduct a longitudinal analysis of the transition from the value proposition and development of transportation mobility technologies in dynamics of the disruptive ecosystem. Finally, the last work uses the Disruptive Ecosystem Evolution model proposed in Article 1 and the comparative scenarios of transportation mobility technologies proposed in Article 3. The article presents a proposal of possible business models and scenarios for the Disruption of the Air Mobility Ecosystem through the arrival of eVTOL technology (ADNER, 2017; CHRISTENSEN et al., 2018; PALMIÉ et al., 2019).

Based on advancing technological development, the market for eVTOLs is taking shape. The technological disruption resulting from this technology could disrupt the current transportation mobility ecosystem. Considering that innovations have the potential to disrupt the configuration of an existing ecosystem (PALMIÉ et al., 2019) and that disruption theory can help to understand the disruption of an ecosystem (CHRISTENSEN, 2006), it is important to understand the evolution of this potentially disruptive ecosystem (DEDEHAYIR; ORTT; SEPPÄNEN, 2017; OGHAZI et al., 2022; PALMIÉ et al., 2019; PUSHPANANTHAN; ELMQUIST, 2022).

While research has been advancing on how individual disruptive companies influence existing businesses and industries, it has not addressed the collective motives and forces why multiple companies cluster around a disruption (CHRISTENSEN et al., 2018; PALMIÉ et al., 2019). Despite the singular value of disruption on individual companies, there is a growing need to understand how organizations collectively create value, substantiating a better understanding of the influence of disruption in the broader systemic context (ADNER, 2012, 2017; ADNER; KAPOOR, 2016; DEDEHAYIR; ORTT; SEPPÄNEN, 2017; OGHAZI et al., 2022).

So far, no studies have been identified that point to the effects of the disruption of eVTOL technology on the existing transportation mobility ecosystem (COHEN; SHAHEEN; FARRAR, 2021; DEDEHAYIR; ORTT; SEPPÄNEN, 2017; OGHAZI et al., 2022; PALMIÉ et al., 2019). Considering the dimension of organizations involved in the constitution of this technology, it is essential to delve deeper into this co-competitive macroenvironment of technological development. These impacts resulting from the disruption in the AAM ecosystem must be identified and studied to understand the eVTOLs disruption in the technological ecosystem and business models.

1.3. Structure of the Thesis

This Thesis follows the structure of scientific articles provided in the "Manual of norms and structure of academic works" (3rd Edition, 2020) of the Federal University of Lavras. This thesis manuscript is divided into two parts. The first part is composed of an Introduction, Theoretical Background, a synthesis of the Methodology of the articles, Final Considerations of the Thesis and References. The second part consists of Articles 1, 2, 3, 4, and 5 which have been either submitted or already approved in scientific journals.

In the First Part, in the Introduction, the Context and Motivation of the research are presented, based on bringing a brief reflection on the importance of studies on Disruptive Innovation and Innovation Ecosystems. The subsection Question Problem, Objectives, and Justifications presents the guiding question of this study, as well as its general and specific objectives, which aim to guide the construction of the five articles that will be part of this study. Finally, this Structure of the Thesis section aims to present the construction of this study for its best presentation.

The Theoretical Framework is mainly composed of the themes of Disruptive Innovation, Innovation Ecosystem and Disruptive Innovation Ecosystems, which are necessary for understanding the Thesis proposal and development of the studies. The Theoretical Framework also presents a contextualization of the development of eVTOL technology and the AAM market. The Methodology section presents a synthesis of the methodologies used to construct the articles.

Then, in the Final Considerations section, the results obtained from the conduction of each article and the general and specific objectives and contributions of this Thesis are presented, followed by the General Reference of the Thesis. In the end, in the Second Part, the five articles and their objectives for this research are presented.

2. THEORETICAL FRAMEWORK

This section aims to present the theoretical foundation for this thesis's construction. Thus, we present the main theories and models that constitute the scope of this study. This reference proposal comprises theories of Disruptive Innovation, Ecosystems, Business Models, and successively, Disruptive Innovation Ecosystems. This section aims to show that the forces, technological or business models, that disrupt a given ecosystem can influence each other and generate new ecosystems based on the disruptive phenomenon.

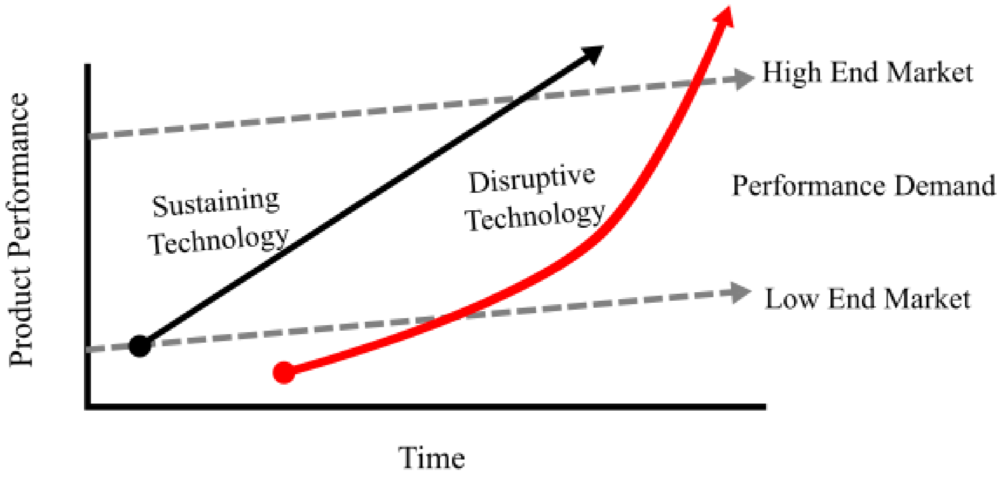
2.1 Disruptive Innovations

Since the birth of civilization, technological changes have always provided profound economic and social changes. Such contexts help understand current technological transformation when investigating the impact of new technologies and examining advanced disruption (CLARKE, 2019; SANDSTRÖM, 2016). In this condition, researchers monitored the evolution and revolution of technology-based factories (CHRISTENSEN, 1997; DEDEHAYIR; ORTT; SEPPÄNEN, 2017). The theory of disruptive technology (CHRISTENSEN, 1997; CHRISTENSEN et al., 2018; CHRISTENSEN; RAYNOR, 2003) is one of the most influential theories on how companies and influencers respond to technological changes (OZALP; CENNAMO; GAWER, 2018). Bower and Christensen (1995) observed that incumbent companies failed to introduce disruptive technologies in the market with a different performance from traditional technologies, while new entrants were successful. Disruptive technologies can be a new technology or a new combination of existing products or technologies that interrupt an established market trajectory (BOWER; CHRISTENSEN, 1995).

Since its first observation in the book The Innovator's Dilemma (1997), the phenomenon of disruption has been identified in different cases of historical failure. The theory highlights how challengers can offer new technologies with a very different value proposition than previously available and oust established incumbents. Christensen e Bower (1996, p. 202) defined disruptive technologies as “technologies which disrupt an established trajectory of performance improvement, or redefine what performance means”. Danneels (2004, p. 249) points out that “a disruptive technology is a technology that changes the bases of competition by changing the performance metrics along which firms compete”. In this way, disruptive technologies change the foundations of competition because they introduce a performance dimension along which products have not previously competed, changing the status quo in the mainstream market.

Figure 1 shows how the theory of disruptive technology was initially proposed.

Figure 1 - Theory of Disruptive Innovation



Source: Adapted from Christensen (1997, p. 12).

The concept of disruption describes a process in which the technology offers features that underperform the dominant technology but with some other features that perform better. Products based on disruptive technologies are usually cheaper, simpler, smaller, and often more convenient to use and may have different functions (CHRISTENSEN, 1997). The new technology attracts niche customer segments not fully served or ignored by the main market (KUMARASWAMY; GARUD; ANSARI, 2018) and who value its differentiated characteristics (CHRISTENSEN; RAYNOR, 2003). Thus, new market disruption aims to create a market where one does not exist and turn non-consumers into consumers (LIU et al., 2020).

So that innovations impact incumbents and challengers differently, many companies choose to build on the current market through existing technology. A historical analysis of disruptions suggests that the continued success of the status quo is unlikely, and the eventual destruction of the core business is almost inevitable (DENNING, 2014). As a result, established companies often fail to adapt to technological changes.

Over time, a disruptive technology moves from the lower end of the market to the higher end (KUMARASWAMY; GARUD; ANSARI, 2018). Thus, established (incumbent) companies that have opted for incremental improvements to existing technology find it difficult to keep up with the competition from disruptive technologies. As part of a process, disruption can take time to supplant dominant technology. When it occurs, the uprise of disruptive technology is fast, and the technological priority of the market changes suddenly (CHAN; FUNG, 2016; CHRISTENSEN, 1997; CHRISTENSEN; RAYNOR, 2003; DANNEELS, 2004). However, it is essential to recognize that only a small part of innovations become a disruption in the market, where most innovations occur in an incremental fashion (BERS et al., 2012).

Subsequently, the concept of disruptive technologies evolved, recognizing that changes in business models cause the phenomenon of disruptive innovations. Disruptors often build business models quite different from incumbents (ZALAN; TOUFAILY, 2017). In this way, disruptive innovation is less related to pure technology, where the incumbent company is paralyzed by the business model of the new operators because it is not feasible to change to the new technology (CHRISTENSEN, 2006). As disruptive innovations differ from existing technological standards and business models in the market (CHAN; FUNG, 2016), disruptors begin to adopt new technology and/or a new business model to create a market that incumbents do not attend (RAD, 2017).

With the term's evolution, many inconsistencies, misconceptions, criticisms, and variations of the theory were found in the literature to describe the phenomenon. Danneels (2004) criticized that disruptive innovation is not limited to low-cost innovation and the new market but can also be high-level. Markides (2006, p. 19) criticized the similarity of disruptive technological innovations and business models, and it is impossible to treat the concepts equally.

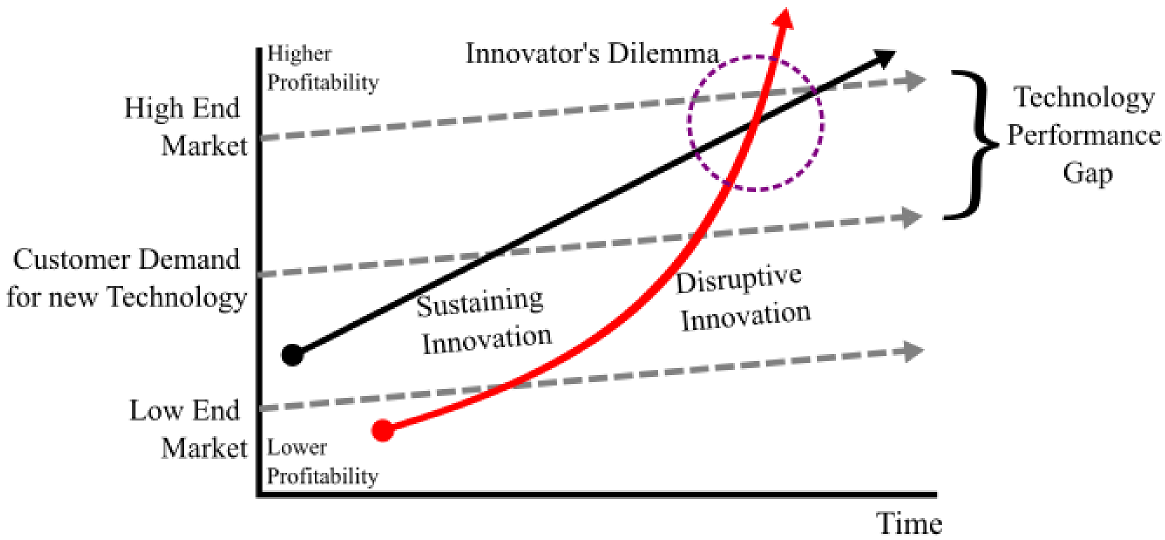
Similarly, the theory of the S-Curve was used in comparison with the theory of disruptions. The S-Curve theory represents the technology life cycle (ADNER; KAPOOR, 2016; CHRISTENSEN, 1997; FOSTER, 1986) where the S-Curve points to the saturation of existing technology and implies a change in technological standards (CHRISTENSEN, 1997). Christensen (2006) points out that the S curve helps visualize technology generation battles. However, the S-Curve does not distinguish between sustaining and disruptive technologies (MIKL et al., 2021) and cannot be used to describe a technological disruption. Disruptions constitute a fundamentally different phenomenon from existing technological standards and cannot be plotted on the same graph and with the same performance metrics as the previous technology (CHRISTENSEN, 2006).

In response to many criticisms, Christensen (2006) relativized that disruptive innovations theory is based on anomalies in business and innovation systems. First, the disruption cannot be described as a preexisting product or technology, as it proposes a new value network and must be seen by its own criteria. This way, the same innovation can increase one company's competencies and destroy another's. Another question is whether disruptive technology will improve to satisfy a specific market level. If it achieves that satisfaction and grows in the core market, that becomes the disruption process. Christensen also recognizes that cutting-edge anomalies can supplant existing technologies, considering they are not low-cost or new markets, but have the same effect and displace the market leader.

With the maturing of discussions regarding the theory of disruptive innovations, different definitions were presented for the concept and helped to develop the theory. Muller (2020) points out that innovation is disruptive if it supplants existing technology and significantly changes the behavior of most stakeholders in that sector. Cozzolino et al. (2018) presented a definition for disruptive business models, where they are business models that interrupt an established model or redefine the meaning of creating and capturing value. According to Chan and Fung (2016), disruptive innovations occur when the innovation destabilizes the order of an existing market and eventually replaces it. Therefore, by definition, disruptions rarely resemble existing products and do not conform to current market norms and paradigms.

According to the increasing definitions of the theory, Christensen et al. (2018) updated the disruptive innovation model, contemplating that disruption occurs as a process over time from inferior markets to superior markets through the performance gaps available in the market. In this innovation dispute, there is the innovator's dilemma and the process of technological substitution. Figure 2 presents this evolution of the disruptive innovation model.

Figure 2 - Disruptive Innovation Model



Source: Prepared by the Author, adapted from Christensen et al. (2018, p. 1048).

Centered on the idea of technological disruption and business models, the definition of disruption was then expanded to include innovations that revolutionize an entire industry and substantially change its competitive patterns and value creation (CHRISTENSEN; RAYNOR;

MCDONALD, 2015; KUMARASWAMY; GARUD; ANSARI, 2018; PALMIÉ et al., 2019). Thus, when integrated into a business model, disruptive technology configures strategic architectures that deliver different mechanisms and redefine the meaning of creating, delivering, and capturing value in markets (PETZOLD; LANDINEZ; BAAKEN, 2019; TEECE, 2010). Disruptive business models are introduced to exploit new disruptive technology (COZZOLINO; VERONA; ROTHAERMEL, 2018).

To condense and clarify the definitions, the Christensen Institute (2021) defines disruptive innovation as a process by which a product or service initially involves simpler applications than those on the market (usually because they are cheaper and more accessible) and then moves relentlessly into the mainstream, eventually displacing established competitors. The Institute points out three elements for disruption: Technology to make the product more accessible; the Business Model, targeting new or marginalized consumers; and the Value Network, which targets disruption prosperity. Thus, disruptive innovations do not revolutionize products and services that are already good but make them more accessible and cheaper, reconfiguring the market value proposition and making them available to a larger population.

In the new value architecture, disruptive innovation is characterized by the development of disruptive technologies and integration into business models (PETZOLD; LANDINEZ; BAAKEN, 2019; TEECE, 2010). All components, technological, business design and value generation intertwine and complement each other (RABIN; KALMAN; KALZ, 2020). After insertion, the disruptive innovation becomes highly competitive among the leading markets because it carries a value proposition central to its initial market (DEDEHAYIR; ORTT; SEPPÄNEN, 2017). In this way, technology itself is not disruptive. Disruption is achieved by capturing technology value within a business model (HABTAY, 2012). Thus, technological innovation and technology business models “are interconnected and constitute an essential part of the disruptive innovation process” (PETZOLD; LANDINEZ; BAAKEN, 2019, p. 5).

2.1.1 Characteristics of Disruptions

A growing body of literature studies how the disruptive process affects market dynamics. Technologies, markets, and institutions influence disruptive activities. Studying these innovations in different scenarios is an opportunity to understand this long-term dynamic process where several factors co-evolve in the market (LIU et al., 2020). To better understand and assess the disruptive dichotomy in different contexts, examining the characteristics of disruptive innovations is useful.

Christensen (1997) initially summarized five characteristics of disruptive technology: 1) Attributes, such as low initial performance that mainstream customers do not value; 2) Target Customers, served marginally or not served by dominant companies/products and who generally value accessibility, simplicity and better cost-benefits of disruptive technologies; 3) Target Markets usually markets that are not critical to dominant players or new and emerging markets; 4) Strategy, where existing companies decide not to invest in disruption because they do not consider it financially reasonable; and 5) Replacement, where new disruptive technology replaces mainstream technology.

Si et al. (2020) described the characteristics of disruption differently. First, disruption is a process and not an event or an outcome. Second, it initially focuses on low-end markets or new markets. Third, their products are generally inferior in attributes that mainstream market consumers value most and superior in attributes most valued by low-end markets. Fourth, your products or services have technological trajectories that are distinct from existing technologies. And fifth, the attributes of disruptive products or services will continue to improve until they meet the needs of consumers in the dominant market. In the proposal by Si et al. (2020), the business model must integrate advantages in the main and marginal attributes to create competitive advantages based on disruption.

Bers et al. (2012) point out that a more radical or disruptive innovation has distinct characteristics that differentiate it from incremental innovation. First, disruptions involve unplanned technological advances that achieve results that normal processes of gradual or incremental improvement of existing technology cannot achieve. These innovations can threaten the current technology base and disrupt established companies' business models and strategies. The second characteristic of disruptions to incremental innovations is that they do not fit within established limits and can interrupt entire industries. The third characteristic is that, while incremental innovation builds on existing technology, disruption requires a complete innovation lifecycle. Lastly, disruption requires deep interconnection, where disruption may not emerge from a single source but from complex global ecologies of actors. For disruptive development, ecologies are responsible for distributing the skills, resources, or influences to guide the development of new technology.

Christensen et al. (2018) revisited the 1997 study and other subsequent research on disruptive innovation theory. In the article, the authors discussed three main characteristics that disruptive innovations emerge in the market. First, it is pointed out that, in many industries, technological progress advances faster than customer demand, producing more advanced and feature-rich products than customers need. This “surplus performance” leaves a gap between the performance provided by companies and the real needs of customers, which new entrants can take advantage of.

The second feature is the distinction between technological and business model innovation. Most of the innovations increase the performance to serve the main market. In disruption, innovations present inferior key features to traditional products with new dimensions of performance that are an opportunity to serve marginal markets or create new ones. Finally, the third component of the disruptive innovation model was that existing business models consider customers, competitors, and profit models. These pre-existing models constrained investments in potentially disruptive new technologies that could serve unprofitable or non-existing customers that would deliver lower initial margins and that targeted smaller markets. Therefore, unattractive investments for holders were an opportunity for new entrants who do not have such roots in pre-existing models and could build a new market (CHRISTENSEN et al., 2018).

2.1.2 Disruptive Innovation and Creative Destruction

When it comes to revolutionary changes, the last few centuries have been marked by technological transformation. Innovations such as mechanization, steam power, combustion engine, electricity, petrochemicals, aviation, digital networks, information technology, and the latest searches for renewable energy sources are some of the waves that brought the recurrent changes. The waves of innovation proposed by Kondratieff (1984) presented a pattern for the cycles of expansion, stagnation and recession of technologies that impact economies and societies. Schumpeter (1942) characterized these waves of innovation as a whirlwind of creative destruction.

Most technological changes consist of modifications that sustain existing technology. A radical or disruptive technological transformation, which brings the discontinuity of dominant technological paradigms, is an agent that allows the search for new opportunities, new social and economic organizations, and new products and processes (CLARKE, 2019). Freeman (1987) pointed out that these more radical technological changes lead to large-scale revolutionary changes. These discontinuities represent new technological systems that affect the economy as a whole, changing production styles, leading to the emergence of a new range of products, services, systems, and industries, changing the management of the entire system and directly or indirectly affecting almost every other branch of the economy.

The concept of creative destruction (SCHUMPETER, 1997) pointed out that, for companies to continue to grow, they must destroy old technologies and products and develop new ones (SABNIS; GREWAL, 2012). To adapt or to perish is an imperative of nature and sentiment to respond to the challenge of technological transformation potential (CLARKE, 2019). Every innovation effort must be associated with developing a business model that defines its market and value capture strategies for innovation to be successful (TEECE, 2010). In this sense, there is an alignment between disruptive innovation and creative destruction, where the business model for disruption is a tool for the creative destruction of an ecosystem (NICOLAÏ; FAUCHEUX, 2015).

Through creative destruction, technologies fundamentally challenge the existing routines, capabilities, and structures by which organizations currently operate, adapt, and innovate (CLARKE, 2019). Change, not stability, is the hallmark of an opportunity for evolution. In this regard, as disruptive innovations appear, old technologies quickly or eventually disappear, as an effect of creative destruction. Thus, disruptive innovations are an opportunity for the development of a dynamic process of co-evolution in different market scenarios (LIU et al., 2020).

The strategic development of the disruptive market by the actors involved is a sustainable way out for operators and disruption. Winners in the global marketplace have been companies that can demonstrate timely responsiveness and fast, flexible innovation. Some companies fail to understand the non-linear dynamics of innovations, where this institutional context threatens their survival. The problem of these organizations is dealing with or initiating revolutionary changes in their markets or dealing with disruptive innovations (RAD, 2017).

As pointed out, disruptive innovation generates a potential for change, breaking with the previous model and generating radical and inevitable changes. As a strategy for the impact of market disruptions, Christensen et al. (2018) argue in favor of hybrid offerings to manage specific market and technology transitions. Hybrid offerings combine features of an emerging innovation (technology or business model) with existing offerings to create a new product or market, introducing an intermediate step between competing generations. Examples such as cars that combine electric propulsion systems with combustion engines are ways of adapting technology that is not aggressive to the existing ecosystem.

Hybrids can be a tool for understanding and adapting to an uncertain future to make the market transition. Hybrids constitute a strategy to leverage new technology while allowing operators to improve existing technology, learn, and adapt to new technology (ANSARI; GARUD, 2009). Christensen et al. (2018) point out that hybrids offer an essential context for disruptive changes. For the author, hybrid products can reach new customers, develop technology hybrids as a go-to-market strategy supporting disruptive technologies, and explore the role of hybrids in corporate business models.

In this case, destruction occurs at the level of an existing ecosystem, technology, and business model, to be replaced by a new ecosystem of technological innovation and business model. Thus, the insertion of a disruptive innovation tends to affect the existing ecosystem. Therefore, it follows the framework for ecosystems in which disruption can have a destructive and constructive effect on a new ecosystem.

2.2 Ecosystem Theory

With a growing number of innovations that disrupt and revolutionize markets (KUMARASWAMY; GARUD; ANSARI, 2018), interest in how innovations affect companies and industries has grown (CHRISTENSEN et al., 2018). These complex systems with the power to impact markets are known as ecosystems (ADNER, 2006, 2017; GRANSTRAND; HOLGERSSON, 2020; HOLGERSSON et al., 2022; PALMIÉ et al., 2019).

An Ecosystem is a set of communities, such as animals and plants, that live in a specific place and interact with each other and with the environment, constituting a stable, balanced, and self-sufficient system. Borrowed from biology, the term ecosystem usually refers to a group of interacting companies that depend on each other's activities (JACOBIDES; CENNAMO; GAWER, 2018). Like the biological ecosystem concept, ecosystem theory proposes similar and evolving market patterns. Therefore, understanding environmental pressures and opportunities make it possible to understand the environmental variables that influence the viability of products and markets (WILLIAMS, 2014).

Moore (1993) developed ecosystem theory to analyze the evolution of different types of businesses. The strategic notion of ecosystem considers beyond rivals that compete within industry boundaries (ADNER, 2017). To understand the strategic approach of ecosystem theory, companies must not be seen as members of a single industry but as part of a business ecosystem that cuts across various industries. The community expressed by the business ecosystem encompasses organizations and individuals in interaction, producing value in the form of goods and services. Within the ecosystem, members develop their capabilities and roles and tend to align themselves in the central direction of the ecosystem pointed out by a leader.

Moore (1993) did not establish a rigorous definition for ecosystem theory. Thus, within the research carried out, the term "ecosystem" itself grew to encompass an ecology of meanings. Adner (2017, p. 4) presented a proposal for the concept, where “the ecosystem is defined by the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize”. This definition helps clarify the construction of ecosystem actors' values. In this sense, the actor's multiplicity of activities and interests make up the ecosystem impact the nature of the strategy. Given this complementarity, ecosystem members exhibit significant interdependence, where each actor's individual outcome depends on the ecosystem's fate as a whole (JACOBIDES; CENNAMO; GAWER, 2018; PALMIÉ et al., 2019).

After the spread of ecosystem theory, its concept became a point of discussion in the strategic area. Its rise in the academic area reflects the importance of theory, and in the market, it reflects the concern with the interdependence between the activities of organizations (ADNER, 2017). To understand this strategic dynamic, it is necessary to have a more precise notion of how ecosystems are structured and governed (JACOBIDES; CENNAMO; GAWER, 2018). At the center of this vision is the ecosystem value proposition, which defines the set of actors and interactions to realize the value proposition (ADNER, 2017). The interdependence of ecosystem members and the products they contribute is, therefore, the main driver of ecosystem Development (DEDEHAYIR; ORTT; SEPPÄNEN, 2017).

To better explain the construction of value relationships proposed by ecosystems, Adner (2017) presents two general distinctions: ecosystem as affiliation and ecosystem as structure. Ecosystem as affiliation sees ecosystems as communities of associated actors defined by their networks and affiliations (e.g., networks, platforms, multilateral markets). The ecosystem as a structure seeks to identify the actors and activities aimed at the value proposition.

The focus of the ecosystem as a structure is the multiplicity of actors that play a critical role in creating and capturing ecosystem value and impacting the nature of the strategy (ADNER, 2017). This definition clarifies where the construction of the ecosystem is relevant and points out four elements of the ecosystem approach as a structure: activities, which specify the actions carried out to materialize the value proposition; actors, which are entities that carry out one or more activities within the ecosystem; positions, which specify the flow of activities between system actors; and links, which specify transfers between actors (material, information, influence, funds). These four elements characterize the creation of value in the interdependent collaboration that is the ecosystem.

Therefore, even when the same actors are involved, the structural reconfiguration of the ecosystem can deliver different value propositions and develop two different ecosystems (DEDEHAYIR; ORTT; SEPPÄNEN, 2017). Thus, in this research, as we will see in the following topics, we use the ecosystem perspective as an innovation structure, emphasizing the activity configurations of the ecosystem value proposition. Next, to better understand an ecosystem's structure and value proposition, the different types of ecosystems will be presented.

2.2.1 Types of Ecosystems

Different aspects of analysis are emphasized depending on different aspects of the ecosystem. Based on a literature review, Jacobides et al. (2018) identified three main groups of studies on ecosystems: (a) business ecosystem (TEECE, 2007); (b) platform ecosystem (GAWER; CUSUMANO, 2008); and a flow of (c) innovation ecosystem (ADNER, 2006; ADNER; KAPOOR, 2010). In the end, we also characterize the (d) support ecosystem that is defended by authors such as Ansari, et al. (2015), Ozalp et al. (2018) and Williams (2014), which will be relevant for conducting this research.

a) Business Ecosystem

The first set of studies, the business ecosystem, focuses on an individual company and is conceived as an economic community composed of different stakeholders, including industrial actors, governments, organizations, competitors, customers, and individuals outside the confines of a single industry, interacting and affecting each other through their activities (JACOBIDES; CENNAMO; GAWER, 2018; MA et al., 2018; MOORE, 1993; TEECE, 2007). The business ecosystem represents an environment in which the company must monitor and react (LI, 2018). It is essential to create and foster the development of emerging technologies and business ideas because all interested actors will facilitate their development, production, and commercialization process (ADNER; KAPOOR, 2010).

b) Platform Ecosystem

The second set of studies focuses on a specific type of technology, the platforms (bi-lateral or multi-lateral markets), and the interdependence between their sponsors and complementors. In this view, the platform ecosystem assumes a leading actor as the leader of the platform to regulate the development of the ecosystem (MOORE, 1993) and a series of complementary companies connected to the central platform that make the platform more valuable for consumers (JACOBIDES; CENNAMO; GAWER, 2018). Connected to the core platform, complementors can drive complementary innovation and broaden customer access to the platform.

c) Innovation Ecosystem

The last set of studies pointed out by Jacobides et al. (2018) focuses on the innovation ecosystem. The emphasis is on understanding how interdependent actors interact to create, develop and commercialize innovations. The innovation ecosystem can be defined as a set of organizations that create value through the production of an integrated and holistic technological system (TEECE, 2007). Collectively, the interdependence of these actors co-develop capabilities around innovation and co-evolve within the market, becoming the main driver of the ecosystem (DEDEHAYIR; ORTT; SEPPÄNEN, 2017; MOORE, 1993). This concept of the Innovation Ecosystem is one of the central concepts of this Thesis and will be better detailed in a later topic.

d) Support Ecosystem

Even though it was not cited by Jacobides et al. (2018) as one of the studies focusing on ecosystem theory, it is important to emphasize the support ecosystem for the development of ecosystems as a whole, especially the innovation ecosystem. Ecosystem theory proposes that successive interactions will exhibit evolutionary patterns. Therefore, understanding the environmental pressures and opportunities that affect the ecosystem makes it possible to understand better what kind of environment an innovation requires to flourish (WILLIAMS, 2014).

Williams (2014) exemplifies the support ecosystem by presenting the evolution of cars and aircraft. The author points out that all major components of a car’s layout (e.g., steering wheel, seats, headlights) are the same as vehicles 100 years ago. Gradual refinement was the main change in vehicles (such as engine efficiency and comfort). The car’s ecosystem (roads, traffic lights, speed cameras, gas stations, tires, batteries) has also evolved over the last 100 years in ways that support the evolution of the car. Without that supportive ecosystem, the car would have much less value and be much less viable. The author suggests that for the car to undergo consistent evolution, the entire ecosystem of the car must support this new evolutionary branch.

In this sense, a single innovation rarely constitutes a complete innovation. For a company to produce innovation and create value for the market, it must fit the critical complements in the market change (ADNER; KAPOOR, 2010). It is important to emphasize that, in an ecosystem, most members are complementors and/or are part of other ecosystems (JACOBIDES; CENNAMO; GAWER, 2018). In this way, the success of individual innovation, however, often depends on the success of other innovations and the evolution of the ecosystem (DEDEHAYIR; ORTT; SEPPÄNEN, 2017).

Emphasizing the different natures of ecosystems, they are not mutually exclusive and can coexist around a business or innovation. Although these views may reflect differences in research focus, they emphasize aspects of the ecosystem that have significant interdependence (JACOBIDES; CENNAMO; GAWER, 2018). Recalling Adner's (2017) proposal, where alignment and interaction between multiple partners are necessary to materialize the ecosystem's value proposition. Regarding this innovation value proposition, follow is presented the innovation ecosystem that has the focus on the creation of value proposition, and that is the focus of this Thesis.

2.2.2 Theory of Innovation Ecosystems

As companies grow and expand their research projects, they attract new partners, leverage external expertise, and create long-term collaboration in an innovation ecosystem. The interaction between multiple partners in ecosystems creates a dynamic and unique environment for the development of innovations (YAGHMAIE; VANHAVERBEKE, 2019). The ecosystem concept explains the nature of the evolutionary interrelations between different actors, their innovative activities, and their environment.

An innovation ecosystem is a collaborative arrangement between organizations to create value they cannot create in isolation (ADNER, 2006). In many sectors, the development of new technologies becomes so expensive and risky that companies combine their expertise to develop more complex innovations (LETEN et al., 2013). Through this collaborative arrangement, organizations emphasize innovation through a mix of collaboration, complementarity, and competition (GRANSTRAND; HOLGERSSON, 2020).

In innovation ecosystems, activities and artifacts that operate in evolution coexist in the form of collaboration, complementarity, and competition, which is important for the innovative performance of an actor or a population of actors (BELTAGUI; ROSLI; CANDI, 2020; MOORE, 1993; PUSHPANANTHAN; ELMQUIST, 2022). The definition by Granstrand and Holgersson (2020, p. 1) adopted in this study indicates that "An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors". Thus, an innovation ecosystem is an association of organizations to create and capture value by developing technical or business innovation activities (ADNER, 2006; ADNER; KAPOOR, 2010). This definition is very close to disruptive Innovation (CHRISTENSEN et al., 2018; CHRISTENSEN INSTITUTE, 2021), which would be the combination of disruptive technologies, disruptive business models and value networks for the development of disruption.

Gomes et al. (2018) argue that in the business ecosystem concept, a competitive focus on capturing value predominates, while the innovation ecosystem emphasizes value creation and collaboration. In this value architecture, there are three recurring entities in ecosystem definitions, actors, artifacts, and institutions, including collaborative/complementary and competitive/substitute relationships, as well as the co-evolutionary nature of innovation ecosystems (GRANSTRAND; HOLGERSSON, 2020; PUSHPANANTHAN; ELMQUIST, 2022; THOMAS; AUTIO; GANN, 2022). In such a way, Granstrand and Holgersson (2020, p. 3) offer a definition where “an innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors”.

In innovation ecosystems, value creation is at the heart of business strategy (JACOBIDES; CENNAMO; GAWER, 2018). The growing trend of joint innovation between companies, or co-innovation, occurs through collaboration between partners in an innovation ecosystem. It allows organizations to increase knowledge transfer and develop their technology. Ecosystem partners play complementary roles around a core company that drives innovation roles. Organizations continually adapt to the requirements of new partners and the wider ecosystem. As partners complement each other, value is co-produced with all partners involved, and companies stop competing with each other and start competing between ecosystems (YAGHMAIE; VANHAVERBEKE, 2019).

Sustainable changes are more manageable for operators and are preferable to radical changes (CHRISTENSEN, 1997). In this case, a technological discontinuity destroys the value of the technological skills of incumbents or distorts established product architectures and is equally harmful to established companies (SANDSTRÖM, 2016). The emergence of a new ecosystem can result in competitive turbulence and change the creation and appropriation of value (GAWER; CUSUMANO, 2014).

Adding to the above, Yaghmaie and Vanhaverbeke (2019) present a broader concept of innovation ecosystems related to the development of an innovative product that requires co-innovation or important complementors; can be used to restructure entire value chains; or for carrying out significant social changes (such as the integration of electric cars or autonomous cars, green energy, the introduction of zero waste or circular economy design). To accomplish these goals, innovation ecosystems must bring together heterogeneous types of partners, including startups, multinationals, local governments, agencies, non-governmental organizations, and communities, among others. Reflecting on the diversity of actors, their complementarity, and interdependence in the creation of value in the innovation ecosystem, the focal value proposition of an ecosystem can be translated into the introduction of a new product or service, or a new way of creating value for customers by creating or changing an existing business model (YAGHMAIE; VANHAVERBEKE, 2019).

So that the greatest value creation depends on the ability of companies to innovate successfully, an innovation may depend on changes in the environment for its own success (ADNER, 2006). These external changes insert the focal company into an ecosystem of interdependent innovations (ADNER; KAPOOR, 2010). Companies operating within a value ecology can no longer separate their own strategy from the ecosystem's needs, and the company's result is the success of the ecosystem ecology. For its own strategy, compatible with the ecosystem, the company must operate as a complex adaptive system capable of responding to changes, opportunities, and threats arising from the value ecology itself (BERS et al., 2012).

When it comes to changes, threats, and opportunities, disruptive innovations can be the disturbance companies are subject to within the ecosystem. Therefore, it is important to understand how these disruptions can affect ecosystems. In this way, the concept of disruptive innovation ecosystem will be presented next, which combines these two theories through the construction of the value network of the ecosystem and disruption.

2.3 Disruptive Innovation Ecosystem

A large number of interruptions can contribute to the abrupt collapse of traditional businesses and create entirely new market ecosystems. Significant technological advances transform business possibilities, where existing companies will reinvent the future markets (DENNING, 2014). Often innovations occur through a stream of radical innovations, consolidating a dominant design and sustaining innovations until another discontinuity occurs. According to Sandström (2016), these discontinuities introduce an entirely new value trajectory that may lead to the downfall of established companies.

Competition in technology-intensive industries is increasingly taking place between ecosystems (BELTAGUI; ROSLI; CANDI, 2020; MOORE, 1993), bringing them a crucial role in emerging new technologies. Technological substitution happens through the evolution of new and old technologies and the ecosystems in which they are inserted (ADNER; KAPOOR, 2016). This suggests that technology disruptions are shaped by factors such as improving an enabling technology, decisions by incumbents and new entrants, and characteristics of the ecosystems in which they operate (CHRISTENSEN et al., 2018).

One of the characteristics of potentially disruptive innovations is that they must be considered along with the innovation ecosystems in which they operate (BELTAGUI; ROSLI; CANDI, 2020; LIU et al., 2020). In turn, ecosystem theory shows that when environmental variables change faster than products or services can adapt, disruption is needed to keep pace. In this sense, the theory considers that any change that affects the entire ecosystem and that offers the opportunity to solve major problems requires a transdisciplinary approach. Thus, disruptive innovation is only possible when the entire ecosystem is considered (WILLIAMS, 2014).

According to Ansari et al. (2015), the juxtaposition of the literature on disruptive innovation and ecosystems reveals a paradox regarding the survival and growth of companies. The disruptor's dilemma points to disruptive innovations as "double-edged swords", where innovations have the potential to generate new markets and disrupt existing ecosystem arrangements. Specifically, the paradox points that companies that introduce disruptive innovations and disrupt existing ecosystem dynamics may need support from the incumbents' technologies, products, or business models that are disrupting. The potential for future benefits for ecosystem members and perceptions of immediate disruption generates coopetitive forces for cooperation and competition between disruptors and incumbents (BELTAGUI; ROSLI; CANDI, 2020).

Some studies have examined the intersection between disruption and ecosystem and have sought to understand how existing ecosystems are affected by disruptive innovations (ANSARI; GARUD; KUMARASWAMY, 2016; OZALP; CENNAMO; GAWER, 2018). Ansari et al. (2015) studied the insertion of new technology in the television ecosystem, where the interaction with incumbent operators became, simultaneously, the problem and the solution for the insertion of the new technology. Sandström (2016) examined how the ecosystem around a potentially disruptive innovation of 3D printing of hearing aids emerged and the alteration of the existing ecosystem. Palmié et al. (2019) present the emergence and impact of disruptive innovation ecosystems around fintech to understand how a disruptive innovation develops a new ecosystem and affects an entire established industry. However, knowledge of how disruptive innovations disrupt existing industries and could constitute new ecosystems is still limited (KUMARASWAMY; GARUD; ANSARI, 2018; OZALP; CENNAMO; GAWER, 2018; PALMIÉ et al., 2019).

In this sense, Palmié et al. (2019) presented the concept of the disruptive innovation ecosystem. The concept combines the definitions of disruptive innovations and innovation ecosystems so that an ecosystem develops and grows around an innovation. By inserting a disruptive innovation into an ecosystem, complementary innovations from ecosystem members can increase the innovation's appeal and emphasize the disruption's potential to dominate the market. Furthermore, a disruptive innovation supported by an ecosystem of disruptors and complementors can grow faster, increasing acceptance of the innovation by ecosystem members, investors, policymakers, regulators, and society at large.

In this proposal, an existing ecosystem can be shaken by a disruption, bringing creative destruction to generate a new ecosystem based on the value proposition and the disruption business model (DEDEHAYIR; MÄKINEN; ORTT, 2018; PALMIÉ et al., 2019). This makes it necessary to analyze the value generated by disruptions through a holistic perspective of the ecosystem (ADNER, 2017; JACOBIDES; CENNAMO; GAWER, 2018). Here, the destruction of the existing ecosystem based on new technology can provoke the entry of new operators into the emerging market (ADNER; KAPOOR, 2016). The competition between companies for a market share, a dominant design, and establishing the best partnerships are part of the business models that design the new ecosystem. For disruptors, the task is to unite a new ecosystem around disruptive innovation to gain access to complementary resources from those responsible for the ecosystem they disrupt (KUMARASWAMY; GARUD; ANSARI, 2018).

To understand the impact of disruption on the existing innovation ecosystem, we follow the "ecosystem as structure" perspective (ADNER, 2017), considering the constellation of organizations that collaborate in delivering the value proposition. However, introducing a disruptive innovation entails a radical change in the attributes appreciated by customers in this market (CHRISTENSEN, 1997; CHRISTENSEN et al., 2018). This new value proposition delivered by an innovation ecosystem will differ from the incumbent operator (DEDEHAYIR; ORTT; SEPPÄNEN, 2017).

Regarding the new value proposition delivered by the disruption to the new ecosystem, the following topics will present some concepts that touch on the theory of ecosystems and disruptive innovations and, consequently, also permeate the theory of ecosystems of disruptive innovations.

2.3.1 Disruption of Ecosystems and New Markets

As a result of stronger disruptions, new products or services are targeted at a different audience than the traditional one and can create entirely new customers and markets (CLARKE, 2019; MARKIDES, 2006). As the disruption grows into the core market, this new constitution shakes up the entire existing ecosystem. How these innovations will transform industries and markets, or even create new industries and markets, will be determined by strategies, business models, and the continuous adaptation of the innovation to existing standards while building new potential standards (CLARKE, 2019).

In this sense, many technologies become outdated to markets, consumers, or the ecosystem itself, requiring an update to keep up with the market or jump into new markets. For example, Petzold et al. (2019) point out that, with the growth of the urban population, the number of vehicles, and the technology itself, much of the infrastructure is outdated for current traffic conditions. In the meantime, cars' form and general function have practically not changed. This is an opportunity to reinvent transportation mobility technologies, develop infrastructure systems and redesign the forms of transport.

This perspective of innovative trajectory change suggests conditions to explore the circumstances in which disruption may occur. Christensen (2006) provides some ex-ante examples of how companies can use the disruption model to achieve growth and even become market leaders instead of falling behind. As a predictive force for the impact of a disruption, organizations should pay attention to (1) a technological concept of a product that has not yet been developed or is under development; (2) a new technology that starts to be manufactured and commercialized; (3) the threat of an innovation that has not yet affected the mainstream market; and (4) the possible future strategy to respond to the possible ongoing disruption. In all cases, the predictive model aims to contribute to a disruption.

Strategic actions with the ability to act flexibly to disruption require an adjustment to the environment to stay on a disruptive path. The implementation of strategic actions requires continuous detection of technological developments, complementary markets, customer demands, perceptions and expectations of holders and other actors, and identification of new opportunities and threats so that it can reconfigure the business model and reach the opportunity of disruption (PETZOLD; LANDINEZ; BAAKEN, 2019). This departs from the theory's dominant perspective that disruption will come from new entrants introducing technologies that target the lower market. To disrupt dominant ecosystems, it is necessary to introduce more advanced technologies with the potential to break the established bonds of complementary ecosystems and prospect technological leaps (OZALP; CENNAMO; GAWER, 2018).

Specifically, concerning eco-mobility, Nicolai e Faucheux (2015) present some characteristics of commercial partnership structures, business models, infrastructure, governance, and social changes that can lead to disruption: (1) the emergence of new technological waves, as currently occurs with electro-mobility; (2) the introduction of new technology by marginal or non-market actors; and (3) the introduction of a new learning curve from the new technology. According to the authors, for the creation of new markets, there must be a virtuous circle of demand for the new possibilities of the new technology and the technological impulse provided by the new products.

These perspectives allow exploring the complexity of disruptions that cannot be fully predicted or understood. According to Christensen et al. (2018), this would require the identification of factors that shield some markets and factors that are underexploited by the main market and that make specific sectors vulnerable to disruptions. However, those adopting a performative perspective of predictability are more likely to learn, take action, and adjust activities in the face of the disruptive phenomenon (KUMARASWAMY; GARUD; ANSARI, 2018).

In this sense, the emergence of a disruptive innovation confronts two ecosystems. The success of the disruptive ecosystem establishes a new structure of actors and connections and reconfigures the value model of the existing ecosystem. Disruptions can offer opportunities for new businesses to enter the innovation ecosystem through a modular or hybrid product/service, where new entrants can take complementary positions that improve the value offering of the ecosystem (DEDEHAYIR; ORTT; SEPPÄNEN, 2017). Such differences and similarities between an ecosystem and a disruptor, the power of disruption stem from ecosystem actors' development. In a rapidly changing business environment driven by disruptive innovation, disruptors must not overlook the power of the forces that build and transform ecosystems. The importance of ecosystems is evident when emerging technologies develop and interdependent companies influence the direct development of technology, skills, and opportunities for new business models (PALMIÉ et al., 2019). Invariably, this disruptive innovation will affect the entire ecosystem, affecting the disruption's development.

Based on the proposed disruptive innovation ecosystem presented, this thesis defends the impact of potentially disruptive innovations of eVTOLs in the transportation mobility technologies mobility ecosystem. To consider the eVTOL development ecosystem, the next topic presents a contextualization of the eVTOL technology and the constitution of the AAM market.

2.4 Air Mobility Market Context

Many prototypes and designs of flying cars were part of the historical development of this technology. The Popular Mechanics website, an essential tool for popularizing scientific and technological publications (COHEN; SHAHEEN; FARRAR, 2021; DEMCHENKO; MALTSEV, 2021; POPULAR MECHANICS, 2021), listed some important milestones in the history of air mobility (COHEN; SHAHEEN; FARRAR, 2021; POPULAR MECHANICS, 2012, 2015). In 1841 William Samuel Henson and John Stringfellow patented the first flying car model, but a working version never was built. Glen Curtiss presented in 1917 a vehicle that had characteristics of a car with wings but that also did not fly. In 1937 Waterman Arrowbile modified a Studebaker car that flew on February 21, 1937, but they produced only five vehicles.

In 1940, with the statement, “Mark my word: a combination airplane and motorcar is coming. You may smile, but it will come”, Henry Ford anticipated the arrival of a form of air transport (BBC, 2013; SILVA, 2022). In 1947 the ConVairCar flying car performed a test flight of approximately one hour. Due to the low fuel level, a forced landing destroyed the car and damaged the plane's wings, postponing the dream of flying a car (POPULAR MECHANICS, 2012).

Several other models have been developed over the years. The Aero-Car in 1966, the AVE Mizar in 1973, the Boeing Sky Commuter in 1980, and the M400X Skycar in 2011 as the first model of a vertical take-off and landing (VTOL) flying car (COHEN; SHAHEEN; FARRAR, 2021; MOLLER INTERNATIONAL, 2016; POPULAR MECHANICS, 2015). Terrafugia's Transition prototype, which has wings that fold and unfold, converting between flight and drive modes, made its first flight in 2012 and is considered the world's first practical flying car (POPULAR MECHANICS, 2015; TERRAFUGIA, 2018).

As shown, many companies have tried to develop this technology in isolation. However, despite numerous attempts, there was no technological and market maturity to take on this change, nor an ecosystem that would allow technology diffusion. However, with the frequent problems related to internal combustion engines and the possible problems of horizontal propulsion vehicle designs, such as the proposal of "flying cars", new technologies would need to be designed.

With the rise of electric batteries to power vehicles, flying vehicles would become cleaner, more economical, and cheaper. Vehicle automation technology also contributed to air vehicles, allowing them to become safer, faster, and work in a fully intelligent manner and on-demand from users. These points would become a breakthrough for environmental, economic and social issues (DIJK; WELLS; KEMP, 2016; GARROW; GERMAN; LEONARD, 2021; SKEETE, 2018). Combined with electrification and automation technologies, the vertical propulsion of vehicles could propose the exploration of airspace as a new route for mobility. Thus, the eVTOL are born (PUKHOVA et al., 2021; UBER ELEVATE, 2016).

While introducing eVTOLs to the market has its gains, some concerns are considerable. Certification and regulation processes will be necessary to adapt to the new reality. New traffic control rules will be needed to accommodate eVTOL routes in the airspace close to large aircraft and smaller drones. A change in the aerial landscape can occur due to the transit of vehicles in the airspace. Cybersecurity issues are also a concern with new technology. A structural change needs to be made to the transport infrastructure to suit the construction of vertiports, eVTOL take-off and landing bases. Issues of cost and acceptance of vehicles by the population. With the advent of the potential disruption of eVTOLs, there may be a reduction in the need for roads, maintenance costs, and congestion, enabling the construction of take-off and landing stations (BOOZ ALLEN HAMILTON, 2018; PRADEEP; WEI, 2019; REICH; COHEN; FERNANDO, 2021; TANG et al., 2021; UBER ELEVATE, 2016). For the development of this future, intelligent, connected, and sustainable traffic management solutions will only emerge through the collaboration of the entire ecosystem (EMBRAERX, 2020).

To integrate eVTOLs into the market, aircraft need to be equipped with information to navigate safely through the airspace, share information and deal with the airspace's large and diverse population density. The eVTOL will combine electric propulsion, autonomous navigation, vertical lift, and other communication and navigation features, and pilot inputs are limited to commanding the desired trajectory. It can expect that autonomous air vehicle navigation will deploy as users and regulators become more comfortable with the technology and see statistical evidence that such technology offers more significant levels of safety than human pilots (PUKHOVA et al., 2021; RAJENDRAN; SRINIVAS, 2020; UBER ELEVATE, 2016).

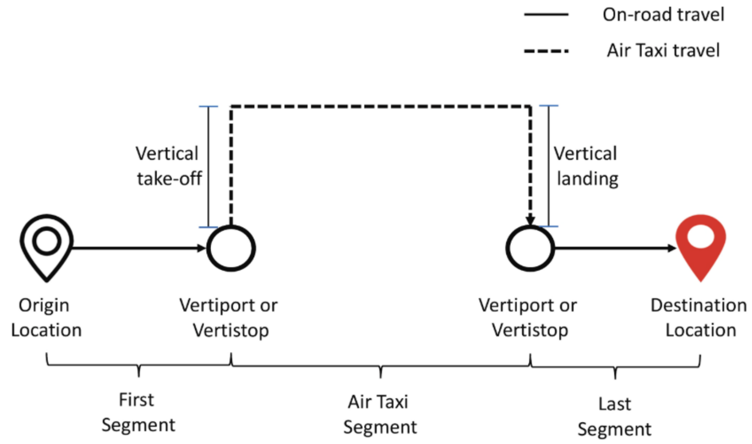
Considering that eVTOLs are a technology that can change or create a new business model for the transportation mobility market, this is a technology with the potential to create a new ecosystem of disruptive innovation (CHRISTENSEN et al., 2018; DEDEHAYIR; ORTT; SEPPÄNEN, 2017; PALMIÉ et al., 2019). A new ecosystem based on eVTOLs can introduce a focus on air mobility with new ways to deliver goods and services faster, more efficiently, more flexibly, and more affordable. Fully on-demand transport routes can bring new solutions and transform the entire transport experience (EMBRAERX, 2020) and become the solution to many environmental, economic, and social problems generated by current CV technology. This new technology has the potential to impact the entire structure of business models in the existing transportation mobility market. In this way, this technological impact is generating the development of a new market, the AAM industry, representing a possible leap forward in the reality of transportation mobility.

Several companies are developing eVTOL technology to make it a reality (PRADEEP; WEI, 2019; VIEIRA; SILVA; BRAVO, 2019), such as Airbus (AIRBUS, 2018), Uber (UBER ELEVATE, 2016), Boeing Aurora (AURORA FLIGHT SCIENCES, 2019), Volocopter (VOLOCOPTER, 2019), Terrafugia (TERRAFUGIA, 2019), Toyota Skydrive (SKYDRIVE, 2019), Ehang (EHANG, 2019) and Embraer (EMBRAER, 2018; EMBRAERX, 2020), among others. As electrification and automation technologies are developed, eVTOLs will also progress in the market (UBER ELEVATE, 2016) and may become the leading transportation mobility solution in shortly future (VIEIRA; SILVA; BRAVO, 2019).

AAM vehicles will improve travel safety and fuel consumption and make trips more Sustainable (AIRBUS, 2018; BELL FLIGHT, 2018; COHEN; SHAHEEN; FARRAR, 2021; REICH; COHEN; FERNANDO, 2021; UBER ELEVATE, 2016). However, there are still disagreements on how the business model of air transport and autonomous vehicles can reach the market. There are proposals for vehicles designed to carry only one passenger or cargo, as well as models aimed at sharing users by air (UBER, 2019) and/or entirely on demand (AIRBUS, 2019). In every sense, Mobility as a Service (MaaS), which integrates various forms of transport services into a single transportation mobility service accessible on demand, seems to be a consensus (MAAS ALLIANCE, 2019).

Compared to other forms of transport (such as taxis, subways, and buses, and even the market for air taxis and medium and short-haul helicopters), eVTOLs can develop routes in different travel segments in real-time, shortening the distances, shortening the duration of trips, in a cleaner way, at much higher speeds, with the elimination of engine noise and costs accessible to the entire population. Therefore, eVTOLs should perform on medium and long-distance trips, initially, they may have higher costs and may be shared (RAJENDRAN; SRINIVAS, 2020; TANG et al., 2021). Without the need for runways, passengers and goods will depart from take-off and landing platforms positioned at different locations in the city, and aircraft, including drones, will be able to coexist safely and quickly. Figure 3 presents the idea of using eVTOLs as air taxis. Users can move from the origin point to a vertiport, travel through eVTOLs, and move from the vertiport to the destination point. These shorter trips between the vertiports and the origin and destination points must be performed by different forms of transport that will support the AAM infrastructure.

Figure 3 - Scheme of a possible trip by eVTOLs.



Source: Rajendran e Srinivas (2020).

In this context, eVTOLs will need a specific space for travel. The space intended for AAM will be between vertiports, aviation airspace and the space for operations carried out by drones (such as deliveries) (EMBRAERX, 2020). Figure 4 represents the delimitations and coexistence of means of transport within the airspace.

Figure 4 - Airspace Delimitations.

Source: Adapted from EmbraerX (2020).

Uber Elevate (2016) pointed out that the main barriers to be faced in bringing on-demand air transport to the market are: the certification process, battery technology, vehicle efficiency, vehicle performance and reliability, air traffic control, cost and accessibility, safety, aircraft noise, emissions, and vertiport/vertical stop infrastructure in cities. The need for pilot training was also pointed out, for the initial demand of the forecast fleet without full automation of the vehicles.

NASA (2018) pointed out the conditions for viability and barriers to the development of the AAM market. The first condition is that there is safety and protection of the vehicles, being necessary to overcome the barriers of regulation and certification, cybersecurity, and air traffic management. The second condition refers to the economy, where investment in infrastructure and accessibility to vehicles is necessary. The third condition is the existence of demand for transport via eVTOLs, where this mode of transport needs to become competitive and there is acceptance by the population to pay for services. Finally, public acceptance, where the perception of transport safety and concerns about the environmental externalities.

Similarly, a report by Booz Allen Hamilton (2018) points out the technological and non-technological challenges for the development of the AAM market. The following technological challenges were pointed out as short-term: the high cost of service driven by capital and battery costs; weather that may affect aircraft operations and performance; high-density management of air traffic; battery technology in terms of weight and recharge times; and environmental impacts that may affect community acceptance. In the long term, the challenges may be: the environmental impacts of large-scale operations; cybersecurity of autonomous systems; disruptions to large numbers of operations during adverse weather conditions; and complexity of airspace management and security across a large number of operations.

Non-technological challenges for the short-term development of the AAM market were pointed out: the lack of existing infrastructure; weather conditions that may compromise safety; the laws and regulations for carrying out the flights; and certifications for aircraft movement in the airspace. In the long-term, the non-technological challenges pointed out were changes in perception related to social mobility to travel time; changes in work scenarios, such as home office, causing a reduction in the need for travel; and processes of urbanization and decongestion that can reduce the viability of markets. Competition with existing means of transport and public acceptance regarding the safety of automation and air transport technologies were possible non-technological problems for the short and long-term (BOOZ ALLEN HAMILTON, 2018).

All these barriers are part of the ecosystem that the new technology will impact. The beginnings of the AAM ecosystem are taking shape. This embryonic market is now open to potential participants from various backgrounds. It can attach importance to different aspects, such as the production of technologies, infrastructure development, navigation, and air traffic management systems. The picture of the potential disruption of the eVTOL ecosystem emerges with the relationships between its different stakeholders and their challenges to be overcome (COHEN; SHAHEEN; FARRAR, 2021; REICH; COHEN; FERNANDO, 2021; ROLAND BERGER, 2018).

By overcoming these barriers, the AAM industry has the potential to offer transportation mobility solutions and economic, social and environmental opportunities. In 2018, the Gartner laboratory classified the AAM trend as possible technology for more than 10 years (GARTNER, 2018). In 2019, this brand become a possible technological trend for the next 2 years (GARTNER, 2019). During this period, will set security, performance, dominant design and business model standards. Technological advances will bring eVTOLs closer to full autonomy. The decisions taken in the next decade will be critical and will determine the implementation, growth and acceptance of the AAM industry (BOOZ ALLEN HAMILTON, 2018; COHEN; SHAHEEN; FARRAR, 2021; EMBRAERX, 2020; UBER ELEVATE, 2016).

3. METHODOLOGY

Table 1 presents the synthesis of the methodologies of each article of this Thesis.

Table 1 - Synthesis of the methodological proposal for the Articles Thesis.

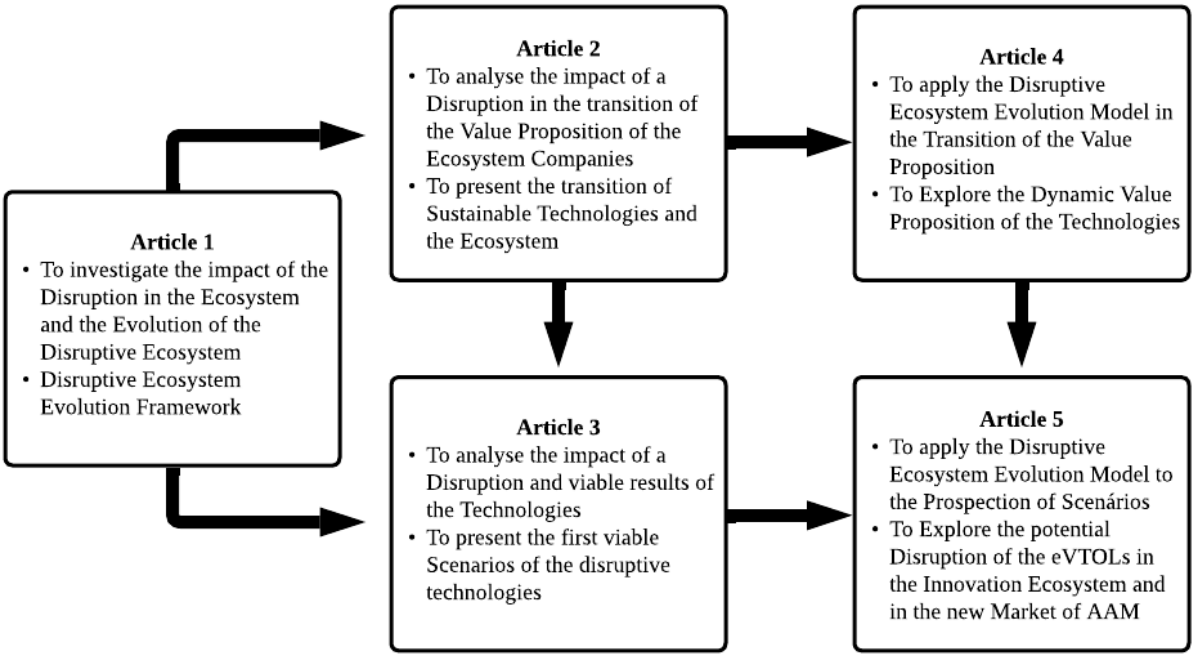
Research Question					
What is the impact of inserting the potentially disruptive innovation of eVTOLs on the transportation mobility ecosystem?					
Main Goal					
To investigate whether the insertion of the potentially disruptive innovation of eVTOLs can impact the transportation mobility ecosystem.					
	Article 1	**Article 2**	**Article 3**	**Article 4**	**Article 5**
Title	The Evolution of the Disruptive Ecosystem: A Framework integrating Disruption, Ecosystems, and Business Models	Disruption in the Transportation Mobility Ecosystem: An Analysis o'f organizational objectives and the Transition to Sustainable Technologies	The effects of Technological Leapfrogging in Transportation Technologies in BRICS and G7 Countries	The Dynamics of Value Proposition within a Disruptive Ecosystem: The Case of Disruptive Transportation Mobility Technologies	The Evolution of Disruptive Ecosystem: A Scenario Proposition for the Disruption of eVTOLs Technology and the Advanced Air Mobility Ecosystems
Purpose	To investigate how disruptive innovation can affect established industries and trigger the development of a new innovation ecosystem.	To analyze how potentially disruptive innovations can change the current technological transportation mobility ecosystem focusing on a sustainable perspective.	To analyze the technological, economic, and environmental impacts of the potentially disruptive innovations in the transportation mobility market	To explore the value proposition dynamics evolution of potentially disruptive innovations in the transportation mobility ecosystem.	To identify and to analyze the possible scenarios for the potentially disruptive innovations of eVTOLs and the advanced air mobility ecosystem
Type of Research	Theoretical Article	Qualitative Exploratory	Quantitative and Qualitative Exploratory	Qualitative Exploratory	Qualitative Exploratory
Study Object	Scientific Articles about disruptive innovations and innovation ecoystems	Mission, Vision and Values of Transportation Mobility Companies	Transport, Economic and Sustainable Data	Gray Literature	Gray Literature
Data Source	Academic Literature	Official Websites of the Companies	World Bank	Reports and Official Sites	Podcasts, Reports and Websites
Data Analysis	Content Analysis	Content Analysis	Comparative Analysis	Content Analysis	Content Analysis
Results	Evolution of the Disruptive Ecosystem Model	Changing the technological transportation mobility ecosystem	Consumption, Economical and Sustainable Reduction	The value proposition for disrupting EVs, AVs and eVTOLs	Scenarios for eVTOLs and the AAM Ecosystem
Article Status	Published in **European Journal of Innovation Management** WoS IF 4,85 Scopus H-Index 67 Qualis Capes: A1	In improvement for submission to the **Transportation Research Part D: Transport and Environment** WoS IF 7,04 Scopus H-Index 113 Qualis Capes: A1	Acceptance with Minor Review in **The Bottom Line** WoS JCI 0,79 Scopus H-Index 19 Qualis Capes: A3	In preparation for submission to the **Technovation** WoS IF 11,83 Scopus H-Index 140 Qualis Capes: A1	In preparation for submission to the **Technological Forecasting and Social Change** WoS IF 10,88 Scopus H-Index 134 Qualis Capes: A1

Source: Elaborated by the author.

4. GENERAL CONSIDERATIONS

The central idea of this Thesis is the impact of a disruption in an ecosystem. To this end, this manuscript is composed of five articles developing the debate of a potentially disruptive disruption of eVTOLs in the transportation mobility ecosystem. Thus, the general objective of this Thesis was "to investigate whether the insertion of the potentially disruptive innovation of eVTOLs can impact the transportation mobility ecosystem". Figure 5 presents the line of construction of each article for this Thesis.

Figure 5 - Context of the Articles in the structure of the Thesis.



Source: Prepared by the author.

As a context and line of development of this Thesis (Figure 5), it is necessary to point out that the Disruptive Ecosystem Evolution Framework (Article 1) shows the impact of a disruption in an existing ecosystem and the development of a new disruptive ecosystem. Also based on the results of changing the ecosystem's value pattern (Article 2) and the prospects of positive results presented in technological replacement (Article 3), it was necessary to deepen this possible ecosystem disruption. Thus, the Disruptive Ecosystem Evolution Framework presents the actors, technologies and forces that drive the development of the new value proposition generated and this new disruptive ecosystem. It is justifiable to use it as an exploratory tool to transition value proposition between technologies (Article 4) and the performativity of ecosystem disruption scenarios (Article 5).

To provide an answer to this objective, Article 1 was carried out as a literature review to understand the insertion of a Disruptive Innovation in an Innovation Ecosystem. It was possible to understand that disruption plays a role in changing the established technological paradigm and business models, transforming the existing ecosystem, and generating new markets. Incumbents and new entrants co-evolve creating and capturing new interconnected value in this complex ecosystem. As a result, it was possible to understand that disruptions can influence the constitution of the Ecosystem, as well as the Ecosystem can influence the success of the disruption.

Article 1 also presented a theoretical framework of "Evolution of the Disruptive Ecosystem" that summarizes the impact of disruption on the ecosystem. This process consists that, when suffering the impact of a disruption in an existing ecosystem, it can generate a new ecosystem with characteristics of old and new actors, technologies, and business models. Internal and external forces influence the new ecosystem in an open and collaborative innovation flow between all ecosystem members in search of developing the disruption. As a result, a new Disruptive Ecosystem emerges based on the disruption that shook the initial ecosystem. Thus, the study proposed the concept of Disruptive Ecosystem Evolution, where actors and technologies evolve based on disruption. Actors disrupt through technologies within the ecosystem, but they can also react to the ecosystem when realizing that the disruption is happening. In this disruptive ecosystem proposal, the actors co-evolve within the innovative ecosystem, building and developing their technologies and business models in a complementary way and reconfiguring the existing value.

Article 2 presented the impact that potentially disruptive and sustainable technologies are bringing to the technological ecosystem of transportation mobility. The article carried out an analysis of the missions, visions and values of the largest companies that produce transport vehicle technologies. The sustainable change of ecosystem actors and technologies was analyzed based on the Sustainable Development Goals. The results point to changes in the strategies of organizations in search of a new market and a more sustainable value proposition. In developing new markets, innovation is a main strategic factor for organizations. Therefore, the objectives converge to developing new, more sustainable transportation mobility technologies focused on EVs, AVs, and eVTOLs.

Article 2 also presented the insertion of companies from the aerospace, software, hardware, and telecommunications sectors in the development of technologies in the transportation mobility sector. This result is indicative of the shift towards potentially disruptive and more sustainable technologies, restructuring the value proposition and restructuring the ecosystem itself. In this perspective, the change in the current technological paradigm, ICE technology, makes room for the new strategic and technological paradigm focused on electric, autonomous, and air mobility technologies.

Article 3 presented impacts related to transport, environmental and economic gains of the potentially disruptive technologies of EVs, AVs, and eVTOLs. The results of inserting these technologies in markets such as the G7 and BRICS were promising for a technological leap in the transportation mobility ecosystem. The leap of potentially disruptive technologies can bring development in transport standards, growth in economic levels and sustainable gains through the reduction of CO2 emissions. Companies can benefit from restructuring value chains and developing new markets and infrastructure related to EVs, AVs, and eVTOLs. The potential disruption provided by new technologies tends to generate new value propositions and tends to be provided by environmental and economic dimensions. Therefore, the scenarios presented in the research indicate that the impact of the disruption of EVs, AVs, and eVTOLs can cause a change in the value proposition that will generate positive results in relation to transport, economics and sustainable, and for the technological leap of the markets in disruption.

With the proposal to insert a disruptive innovation in an ecosystem and the Disruptive Ecosystem Evolution Model (Article 1), and the change in the value proposition of companies and technologies in the transportation mobility ecosystem (Article 2), Article 4 presented a longitudinal case study to explore the value proposition transition of technologies from EVs, AVs, and eVTOLs. The study used documents and official websites of technology development and specialized consulting companies. The Disruptive Ecosystem Evolution model was applied to analyze the Evolution Dynamics of the Value Proposition of EVs, AVs, and eVTOLs technologies in the transportation mobility ecosystem.

The results of Article 4 sheds lights on the entry of new technologies and new companies in changing the value proposition of the ecosystem (corroborating the results of Article 2). When a disruption occurs, the ecosystem seeks to adapt to the disruptor and the disruptive effect, creating a space for developing new technologies. This impact of technology on actors due to disruption generates a process of adaptation to the new ecosystem mosaic form, with part of the capabilities of incumbents and new operators in this ecosystem. Collaboration is a fundamental factor for the value proposition dynamics and the evolution of new ecosystems.

Article 4 proposes the concept of a “Dynamic Value Proposition” where the value proposition accompanies the disruption and adaptively evolves along with the ecosystem. This dynamic of evolution and adaptation of the value proposition of the disruptive ecosystem constitutes the new Value Ecosystem. These findings align with the disruptive ecosystem's theoretical proposal in which the entire ecosystem adapts to disruptive change. Therefore, based on the disruptive impact of EVs, AVs, and eVTOLs, the Dynamics of the Evolution of the Value Proposition is part of the evolution and adaptation process of actors and technologies to the new disruptive ecosystem of transportation mobility.

Finally, Article 5 made use of the Disruptive Ecosystem Evolution Model (Article 1), the proposed scenarios and the technological leap (Article 3), and the transition and dynamics of the value proposition (Articles 2 and 4) to deepen the analysis of possible scenarios of the impact of the potentially disruptive innovation of eVTOLs in the transportation mobility ecosystem. The article aims to understand that disruptive technology and a business model create disruptive ecosystems. This allows us to associate the performativity and predictability of the disruption found in the change in technology impacts on the ecosystem. Thus, the article used documents and official websites of technology development and specialized consulting companies and used interviews from a podcast specialized in the development of the eVTOLs market to apply the Disruptive Ecosystem Evolution model as a performative tool of market scenarios.

Article 5 corroborates the proposal presented in the Disruptive Ecosystem Evolution Model (Article 1), where there is a co-evolutionary process based on several necessary technologies that converge to the disruptive process of eVTOLs. The results of Article 5 are also in line with Article 3, where when a disruption impacts an ecosystem, it can evolve and trigger a possible technological leap for the ecosystem. Article 5 also confirms the findings of Articles 2 and 4, where collaboration between actors from different sectors is fundamental for developing eVTOL technology and the AAM market.

The results of Article 5 also present the evolutionary leap of the ecosystem accompanied by a dynamic value proposition that constitutes the new disruptive ecosystem (Article 4). The results of Article 5 also point to the association of actors' strategies for technology success within the ecosystem. With this, it was possible to present a proposal for the Innovation Biome to expand the scope of technologies that involve the different technological ecosystems that are part of the eVTOLs. This proposal of an innovation biome, or disruptive biome, is aligned with the collaborative, adaptive and evolutionary process of the multiple ecosystems that are part of the core disruption in process. Corroborating the previous results, Article 5 also raises the consideration of the impact of a disruption in the ecosystem, this evolution of the disruptive ecosystem occurs based on the technology of eVTOLs, being able to create the new AAM market.

The central Thesis of this research is that the process of disruptive innovation can shake an existing ecosystem, restructuring the value proposition. This process will create an evolution of the innovation ecosystem around the disruption and emerging a new market (business ecosystem) based on the new technologies and the new business model. Thus, related to eVTOL technology and the AAM market, the research question of this Thesis investigates "What is the impact of inserting the potentially disruptive innovation of eVTOLs on the transportation mobility ecosystem?".

To answer this question, using the Evolution of the Disruptive Ecosystem model (Article 1), it was possible to analyze the impact of eVTOL technology on the innovation ecosystem of the transport sector. As shown in the model, the impact of eVTOLs generates an evolutionary and dynamic effect. As companies' objectives and strategies change towards new technologies, the disruptive ecosystem generated by the new technology tends to alter and reconfigure the existing technological ecosystem (Article 2). The economic, social, and environmental impacts of new transport technologies also indicate the potential impact of disruption across the entire market (Article 3). According to the results, changing the value proposition of the transition to new transport technologies is part of the disruptive process and the creation and evolution of new ecosystems (Article 4). Consecutively, this new technological ecosystem of eVTOLs is in its initial phase, creating the foundations for the development of the ecosystem, and tends to create a new disruptive AAM market that is not served by existing technologies (Article 5). Thus, based on this study of the new technology of eVTOLs, it is possible to show that potentially disruptive innovations can affect existing ecosystems and lead to the generation of disruptive ecosystems.

The objective of this Thesis is to investigate the impact of the potentially disruptive innovation of eVTOLs in the transportation mobility ecosystem. It is possible to conclude that the Disruptive Ecosystem Evolution Model presented is a viable tool for analyzing the impact of disruption in the ecosystem and perform the constitution of the new disruptive ecosystem. Another valuable result of this Thesis is the transition dynamics of the value proposition of transportation mobility technologies. It is also valuable to understand the restructuring of the entire value creation and capture chain to address eVTOL technology. The collaboration factor of different actors is indicative of ecosystem change in favor of disruption. Another result beyond this Thesis's objective comes from the evolution of the innovation ecosystem of eVTOLs and constitutes the disruption of new AAM markets. It is possible to infer that a disruption generates an impact in the innovation and business ecosystem. Thus, the impact of the potentially disruptive innovation of eVTOLs in the transportation mobility ecosystem can generate the process of evolution of the existing innovation ecosystem and constitute the disruption of the new AAM market.

As a theoretical contribution, this Thesis sought to combine the Disruptive Innovation and Innovation Ecosystem theories. This Thesis presented the Disruptive Ecosystem Evolution Model that proved to be a viable tool to perform the transition of the value proposition between technologies and the performativity of scenarios of the impact of disruption. It also contributed to broadening the understanding of the impact that disruption has on the ecosystem and the influence of ecosystem forces in the direction of the disruption. These forces can point to a disruption, evolving the value proposition and generating technological leaps for the entire ecosystem. As a practical contribution, this Thesis contributed to understanding the disruptive potential of eVTOLs and presented changes in the value proposition and possible scenarios for developing eVTOL technology. In this way, we seek to help identify opportunities and threats in the face of disruption and reconfiguration of a market ecosystem. Prospecting possible scenarios, business models, and the value proposition also seeks to help learning, decision-making and flexibility in developing the disruptive ecosystem of eVTOLs and in the constitution of the new AAM market.

As for this thesis' limitations, we highlighted the solely employed theoretical model of Disruptive Ecosystem Evolution to a single industry sector. It is suggested to apply the model to analyze the impact of disruptions in other sectors and ecosystems. This thesis was also limited to collecting secondary data. It is suggested to expand the scope of analysis by collecting primary data such as questionnaires, interviews, and focus groups, among others. The technology and company cases cited were also limited to those presented in the reports. It is suggested to expand the cases from the researched industry and other market sectors. The helicopter technology and market can be studied to understand the innovator's dilemma, whether to improve the existing technology or join EVTOLs' potentially disruptive technologies within the AAM market.

As the eVTOLs technology and ecosystems are incipient, new research can analyze patent count and citations or funding and social networks to understand the value dynamics of the nascent innovation ecosystems. It is also suggested to investigate the pre-competitive coalitions in the innovation ecosystem development. Also, given the technology and ecosystem's incipiency, it is an opportunity to conduct a Life-cycle Assessment of a developing potentially disruptive technology. Another limitation is that the technology is in its early stage, and the collected data only refers to the current moment, where new forces can impact the disruptive ecosystem. Therefore, further research is suggested for monitoring the ecosystem and the market.

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SECOND PART – ARTICLES

"If you don't take risks, you can't create a future"

(Eiichiro Oda).

ARTICLE 1 – THE EVOLUTION OF THE DISRUPTIVE ECOSYSTEM: A FRAMEWORK INTEGRATING DISRUPTIN, ECOSYSTEMS, AND BUSINESS MODELS

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Purpose must be deliberately conceived and chosen, and then pursued.
(Clayton M. Christensen).

THE EVOLUTION OF THE DISRUPTIVE ECOSYSTEM: A FRAMEWORK INTEGRATING DISRUPTION, ECOSYSTEMS, AND BUSINESS MODELS

João Paulo Nascimento da Silva
André Grützmann

Abstract
Purpose – This article aims to understand the dynamics between disruptive innovations and innovation ecosystems, using disruption business models as a catalyst.
Design/methodology/approach – This study presents an integrative literature review and a theoretical framework in order to integrate the theories of disruptions and ecosystems.
Findings – The dynamics of disruptive innovation, within an ecosystem, as an essential driver of creating new markets. The effect of creative destruction from a disruption influences business models in a coopetitive dynamic that drives the ecosystem as a whole.
Research limitations/implications – Limited to theoretical research and suggested the application of the proposed model in an empirical study.
Practical implications – Understand the formation of new ecosystems based on the occurrence of a disruption as a way for organisations to prepare for the arrival of this new market.
Originality/value – The contribution of this study is based on joining the literature of disruptive innovation and innovation ecosystem, pointing to a theoretical framework and a flow of Evolution and Adaptation to the Disruptive Ecosystem that integrates this complex dynamic.
Keywords - Disruptive innovation, Business model, Innovation ecosystem, Disruptive ecosystem.
Paper type - Literature Review.

1. Introduction

After stating that through creative destruction, technological changes can alter the competitive industrial pattern and structure (Schumpeter, 1942), some studies examined the evolution and revolution of technology-based industries (Christensen, 1997; Dedehayir et al., 2017; Sandström, 2016). The theory of disruptive innovation (Christensen, 1997; Christensen et al., 2018; Christensen & Raynor, 2003) is one of the most influential theories on how companies and industries respond to technological changes (Ozalp et al., 2018). Bower and Christensen (1995) observed that incumbent companies failed to introduce disruptive technologies in the market with a performance different from traditional technologies, while new entrants were successful (Christensen, 1997; Christensen & Raynor, 2003). Disruption occurs when the new technology overcomes the current one and becomes dominant (Adner, 2002).

Subsequent studies suggested adopting the term disruptive innovation, given that the phenomenon is related to changes in business models (Christensen, 2006). New entrants create new value propositions and manage to capture value, initially uninteresting to incumbents (Petzold et al., 2019; Teece, 2010). Therefore, disruption is not achieved by the technology itself but by its integration into a business model (Habtay, 2012; Petzold et al., 2019).

With an increasing number of disruptions that remodel the way companies and industries operate (Kumaraswamy et al., 2018), there has also been growing interest in how disruptive innovations affect companies and industries (Christensen et al., 2018). Innovation ecosystems are known as systems with the power to impact markets (Adner, 2006; Granstrand & Holgersson, 2020; Palmié et al., 2019). An innovation ecosystem is a collaborative arrangement where companies create technical or business innovation value that could not be made in isolation (Adner, 2006; Yaghmaie & Vanhaverbeke, 2019). Innovation ecosystems operate through evolving actors, activities, artefacts, and complementary and substitutive institutions and relationships, emphasising collaboration, complementarity and competition among actors (Granstrand & Holgersson, 2020; Moore, 1993). From the disruption, new operators can enter the ecosystem with the new technology or new business model (Christensen et al., 2018), or they can start from the very complementors that participate in the value structure of that existing ecosystem (Adner & Lieberman, 2021). Thus, the product ecosystem theory shows that disruptive innovation is only possible when the entire ecosystem is considered (Williams, 2014).

Competition in intensive technology industries occurs more among ecosystems (Moore, 1993), enabling technological discontinuities (Sandström, 2016). The literature on innovation ecosystems emphasises an ecology of complementary and interdependent companies (Adner, 2012). Chesbrough (2003) states that open business models describe how a company creates and captures value by taking advantage of its internal and external business. Thus, an innovation ecosystem implies that the coevolutionary dynamic occurs within an ecosystem in permanent exchange with environments for continuous innovation (Hou & Shi, 2020) and sews a network of value to establish disruptive innovations (Adner & Kapoor, 2016; Brandenburger & Nalebuff, 1996).

Theories of disruptive innovations and ecosystems cross where disruptions must be considered alongside the innovation ecosystems in which they appear (Beltagui et al., 2020; Liu et al., 2020). Disruptions are generally developed and commercialised in ecosystems and not in isolated companies (Ansari et al., 2016; Kumaraswamy et al., 2018). Academic research still seeks to understand how disruptive innovations affect existing ecosystems (Dedehayir et al., 2017; Palmié et al., 2019). There is a lack of studies on how disruptive innovations can constitute ecosystems and disrupt existing industries (Kumaraswamy et al., 2018; Ozalp et al., 2018). A rapidly changing environment driven by disruptive innovation must not neglect the forces that build and transform ecosystems (Kumaraswamy et al., 2018; Palmié et al., 2019). The importance of an ecosystem is visible when interdependent companies participate in developing emerging technologies affecting their business models (Adner, 2017; Adner & Kapoor, 2016).

Understanding the ecosystem where disruptive innovation occurs can help interpret and analyse the distinctive value proposition promoted in the new ecosystem (Tsujimoto et al., 2018). This awareness would provide a broader picture of how incumbents and the next generation of innovators deal with new competitors and how ecosystem actors influence each other through emerging technologies and business models (Palmié et al., 2019). Will disruptive technologies and business models affect established ecosystems leading to reconfigure the existing value? This study investigates how disruptive innovation can affect established industries and trigger the development of a new innovation ecosystem. Investigating the underlying ecosystems where disruptive innovation occurs can help evaluate the influence of new business models and the ecosystem competition (Dedehayir et al., 2017; Palmié et al., 2019). While many studies focus on how an ecosystem emerges around an innovation (Dedehayir et al., 2017; Kumaraswamy et al., 2018; Palmié et al., 2019), this paper contributes to new insights on a disruption affecting the development of a new ecosystem.

The remainder of this document begins with a description of the methodology. In section 3, the results of the integrative literature review are presented and discussed. Section 4 integrates the theories followed by a framework proposition and its explanation. The paper ends with conclusions, limitations and suggestions for future studies.

2. Methodology

This study used an integrative literature review to organise similar ideas and provide new perspectives on emerging topics (Snyder, 2019; Torraco, 2005, 2016). The Clarivate Analytics Web of Science (WoS) and Scopus Elsevier (Scopus) databases were chosen because they are significant sources of citation data, and their interdisciplinary coverage represents a strong point for comparing distinct scientific fields (Mongeon & Paul-Hus, 2016)

The search contemplated Disruptive Innovation and Ecosystem themes in conjunction, using the appropriate Boolean operators (“disruptive innovat*” and “ecosyste*”). The query covered titles, abstracts, and keywords, filtering only scientific articles from all thematic areas. Even if the integrative literature review does not need to cover all papers published for a given subject (Snyder, 2019), the search sought all articles with both themes without limiting the search timeframe. The first result was from 2007.

The search resulted in 57 scientific articles, 27 from Web of Science, and 30 from Scopus. Eighteen duplicate papers and one written in a language other than English were eliminated. The remaining 38 articles were read in full, leading to the exclusion of 17 works that only cited the keywords without deepening them. Thus, 21 articles were part of this research. Table 1 presents a summary of the steps and guiding factors for the research.

Table 1 - Stages of the Integrative Review

Review Steps	Description of the Steps	Results obtained
Step 1 Selection Criteria	Database	Clarivate Analytics Web of Science Scopus Elsevier (Scopus)
	Years of Search	Until April 2020
	Search Terms	“disruptive innovat*” and “ecosyste*”
	Partial Articles Total	57
	Duplicate Articles Exclusion	18
	Partial Articles Total	38
	Reading and Deleting Articles Out of Scope	17 excluded articles
	Total Articles for Analysis	21
Step 2 Analysis Criteria	Analysis of the results obtained by the research (Tabulation in Excel)	
	Synthesis of Knowledge	
	Construction of Categories	
	Critical analysis	

Source: Research Data.

The data were tabulated in spreadsheet software to help the analysis. The topics presented in the results and discussion section emerged according to the literature analysis, verifying thematic convergences (Torraco, 2005, 2016) within the authors' proposals and integrating the reviewed literature's main ideas. Table 2 presents the analysed papers.

Table 2: Disruptive Innovation and Ecosystem Articles.

Article	Author	Year	Journal	Base
The evolution of the financial technology ecosystem: An introduction and agenda for future research on disruptive innovations in ecosystems	Palmié, M.; et al.	2020	Technological Forecasting and Social Change	WoS, Scopus
Exaptation in a digital innovation ecosystem: The disruptive impacts of 3D printing	Beltagui, A.; et al.	2020	Research Policy	WoS, Scopus
The cathedral’s ivory tower and the open education bazaar–catalyzing innovation in the higher education sector	Rabin, E.; et al.	2020	Open Learning: The Journal of Open, Distance and e-Learning	Scopus
Facing Disruption: The Cinema Value Chain in the Digital Age	Salvador, E.; et al.	2019	International Journal of Arts Management	WoS
Fintech and regtech: Impact on regulators and banks	Anagnostopoulos, I.	2018	Journal of Economics and Business	WoS, Scopus
Perspectives on Disruptive Innovations	Kumaraswamy, A.; et al.	2018	Journal of Management Studies	WoS, Scopus
Disruptive Innovation: An Intellectual History and Directions for Future Research	Christensen, C. M.; et al.	2018	Journal of Management Studies	WoS
Unpacking the Disruption Process: New Technology, Business Models, and Incumbent Adaptation	Cozzolino, A.; et al.	2018	Journal of Management Studies	WoS

Disruption in Platform-Based Ecosystems	Ozalp, H.; et al.	2018	Journal of Management Studies	WoS, Scopus
Co-evolution between urban sustainability and business ecosystem innovation: Evidence from the sharing mobility sector in Shanghai	Ma, Y.; et al.	2018	Journal of Cleaner Production	WoS, Scopus
Fintech: Ecosystem, business models, investment decisions, and challenges	Lee, I.; Shin, Y. J.	2018	Business Horizons	WoS, Scopus
The Promise of Fintech in Emerging Markets: Not as Disruptive	Zalan, T.; Toufaily, E.	2017	Contemporary Economics	WoS, Scopus
A new perspective on the innovator's dilemma - exploring the role of entrepreneurial incentives	Berglund, H.; Sandstrom, C.	2017	International Journal of Technology Management	WoS
Disruptive change and the reconfiguration of innovation ecosystems	Dedehayir, O.; et al.	2017	Journal of Technology Management and Innovation	Scopus
Rebalancing Competition Policy to Stimulate Innovation and Sustain Growth	Chan, J.; Fung, H.	2016	Asian Journal of Law and Economics	WoS
When Harry met Sally: different approaches towards Uber and AirBnB-an Australian and Singapore perspective	Tham, A.	2016	Information Technology & Tourismo	WoS, Scopus
The disruptor's dilemma: TiVo and the US television ecosystem	Ansari, S. S.; et al.	2015	Strategic Management Journal	WoS, Scopus
The non-disruptive emergence of an ecosystem for 3D Printing - Insights from the hearing aid industry's transition 1989-2008	Sandström, C. G.	2016	Technological Forecasting and Social Change	WoS, Scopus
Business models and the diffusion of eco-innovations in the eco-mobility sector	Nicolai, I.; Faucheux, S.	2015	Society and Business Review	WoS
Extending the stage-gate model to radical innovation - The accelerated radical innovation model	Bers, J. A.; et al.	2012	Journal of the Knowledge Economy	Scopus
Innovating the development of innovation	Tatum, D.	2007	Research-Technology Management	WoS, Scopus

Source: Research Data.

The study categories emerged while reading the texts, with Disruptive Innovation, Ecosystem, and Business Models concepts provided guidance. With the convergence among the guiding principles, the articles could belong to more than one category. During the analysis, the main topics discussed within each category were found and are presented below.

3. Results and Discussion

This section synthesises the multidisciplinary literature to understand the dynamics between disruptive innovation and the innovation ecosystem. The results are presented based on three topics: Disruptive Innovation, which includes technological and business model disruption (Christensen et al., 2018; Christensen & Raynor, 2003); Ecosystem, as constitution and impact on the market (Adner, 2017; Granstrand & Holgersson, 2020; Moore, 1993; Palmié et al., 2019); and business Models as a catalyst for this dynamic (Christensen et al., 2018; Palmié et al., 2019; Petzold et al., 2019). Each topic was divided into subtopics according to the literature. This section ends with a framework that aims to integrate and synthesise the disruptive phenomenon in ecosystems in an attempt to answer the research question.

3.1. Disruptive Innovation

To understand how radical technological changes can affect companies and their markets, disruptive innovation studies the dynamics of how technological transitions introduce new performance and bring down established industries (Christensen et al., 2018; Cozzolino et al., 2018; Dedehayir et al., 2017; Sandström, 2016). As a result of the disruption, the innovator faces the dilemma of creating a new market or integrating the ecosystem experiencing the disruption.

Disruption is understood not as a single event but as a process that affects and reconfigures relational interdependencies between members of the ecosystem (Ansari et al., 2016; Christensen et al., 2018). Thus, disruption can break with established models, make business models, networks and value proposals obsolete, supply structures and value delivered to customers, generating significant market transformations until institutions incorporate disruptive innovations (Ansari et al., 2016; Kumaraswamy et al., 2018). In this way, disruption can transform markets by influencing the competitive dynamics among new participants and incumbents (Berglund & Sandström, 2017), where the power of disruptions will manifest itself as markets evolve (Lee & Shin, 2018; Ma et al., 2018).

Salvador et al. (2019) highlight the disruption in the film industry, where a new type of interaction among technology, players, content creation, and production drive transformations. New actors were using technology to serve the creative dimension of works and changed the value chain. Netflix was part of the digitisation revolution, and this expanded its relationship with customers by identifying consumer preferences.

Netflix streaming format was a threat to the traditional television business model. Netflix innovated by using new technologies to engage new segments of the value chain, introduce new forms of payment, connect with consumers, and recognise consumers' preferences to view content whenever and wherever they want. The data collected by Netflix's video-on-demand platform offers consumers personalised television products. Thus, through consumer preferences, Netflix can target programs and advertising. According to Salvador et al. (2019), the balance between technological innovation and artistic creation is evolving towards a more technological orientation, both in production and distribution. The film industry is witnessing the emergence of a new digital ecosystem, where media consumption is shifting from push to pull.

3.1.1. Creative Destruction

New technologies allow new and better products to displace the dominant products in the market (Chan & Fung, 2016). Thus, the concept of disruptive innovation analyses the development of markets in the face of technological innovations, is aligned to the creative destruction concept inside the entire ecosystem (Dedehayir et al., 2017; Nicolai & Faucheux, 2015).

The reconfiguration of the ecosystem provides a new value project in the face of disruption (Dedehayir et al., 2017) and cultivates innovations within the ecosystem (Beltagui et al., 2020). Events such as the emergence of new technologies, new technological waves, the introduction of technologies by marginal actors or even actors outside the established market, or the introduction of new technologies in value networks are an express part in the emergence of new market structures (Nicolai & Faucheux, 2015). Disruption can occur through a combination of continuous and discontinuous technological changes, creating opportunities, uncertainties, and the entry of new operators (Sandström, 2016).

For example, Sandström (2016) shows the rise of 3D printers quickly adopted in hearing aids. 3D printing was a technology that allowed the industrialisation and customisation of a manual process, with quality problems and impossible to standardise. Complementary technologies were also needed to produce hearing aids, such as 3D scanners and software for three-dimensional modelling. 3D printing affected competencies, complementary assets, the external environment of companies, and their incentive to invest in new technology. In this sense, 3D printing replaced the existing production process of hearing aids, having a significant impact on the competitive scenario.

Part of the evolutionary process is the combination of new resources, technologies, and value chains (Nicolai & Faucheux, 2015), where eventually a dominant design appears, and the competitive scenarios begin to consolidate until the arrival of a new disruption. Considering these technological transitions between generations, advances in disruption are potentially disruptive to the established ecosystem (Ozalp et al., 2018; Sandström, 2016).

In this sense, Nicolai and Faucheux (2015) point to innovation as a tool for creative destruction to integrate new forms of value creation. Their study on eco-mobility applied to Autonomous Vehicle technology has implications that substantially change the configuration of the urban transport market. Eco mobility implies new partnerships for the development of technology and production; creates a new configuration of social demands for environmental performance, comfort, and flexibility for users of different ages; it implies new marketing strategies and business models aimed at a service economy; and accounts for a new configuration of the regulatory environment. From the technology of autonomous vehicles, innovation in eco-mobility constitutes substantial destruction of the existing ecosystem of the transport and urban mobility markets.

3.1.2. Historic Operators and New Operators

Initially, the Disruptive Innovation theory pointed out that incumbents ignored disruptions and, later, were replaced by new entrants (Christensen et al., 2018). However, while disruption can break established links with complementors in the ecosystem (Ozalp et al., 2018), an incumbent may offer a sustaining innovation or a disruptive equivalent innovation to compete with the challenger. In this way, innovation takes time to generate a disruptive impact, and connections to the ecosystem must be established so that innovation can evolve (Beltagui et al., 2020; Kumaraswamy et al., 2018).

It is common for new participants to take over and reshape the industry (Palmié et al., 2019; Tatum, 2007). If the disruptive innovation differs substantially from the exploitation capabilities of the prior technology, the disruptors will be better positioned to benefit from the discontinuity (Berglund & Sandström, 2017). The incumbent operators can still exploit disruption if their capabilities are essential and difficult to imitate by new participants (Zalan & Toufaily, 2017). Historical operators are incorporated into a vast network of actors to cultivate relationships that allow them to sustain their business models (Berglund & Sandström, 2017).

Thus, a characteristic of the innovation ecosystem is that the established actors have been collaborating with the new participants, bringing the necessary accessories for the development of the disruption (Nicolai & Faucheux, 2015), and the traditional institutions, which initially treat the new operators as threats, they can change their focus to collaborate (Christensen et al., 2018; Cozzolino et al., 2018; Lee & Shin, 2018). This collaboration leverages the provisions of established companies with the technological insights and business models of start-ups to transform the market (Berglund & Sandström, 2017; Lee & Shin, 2018). This change in the value chain, with the integration of new actors into the existing ecosystem, can be a source of competitive advantage to face disruption (Nicolai & Faucheux, 2015; Zalan & Toufaily, 2017). Here, the capabilities of incumbents and new entrants can become complementary factors in the face of disruption.

Regarding the complementary capabilities between incumbent operators and new entrants, Zalan and Toufaily (2017) investigated how the traditional financial services sector perceives the effect of digital disruption and the strategies adopted from fintech companies. The research points to very different sets of capacities in the banking sector and fintech companies. Financial institutions have the advantage of scale, confidence, a customer base, resources to thrive in challenging economic conditions, and well-protected by regulations. Fintech companies can offer a highly focused solution, are more accessible, agile, flexible, creative, have a better cost-benefit and offer an enhanced and personalized experience to the customer, and explore the power of digital technologies to add value. The results point to a collaborative future, where the capabilities of new operators and incumbents become complementary to face the adversities of disruption.

3.2. Innovation Ecosystem

Ecosystems are networks of interconnected and interdependent companies in their businesses that produce an integrated and holistic technological system (Ansari et al., 2016; Dedehayir et al., 2017; Rabin et al., 2019). An innovation ecosystem comprises different actors who live in the same economic scenario and co-evolve with each other. Together, these actors co-develop capabilities around innovation and play a role in the dynamics of a complex and adaptive ecosystem through competition and cooperation in search of survival and dominance (Kumaraswamy et al., 2018; Palmié et al., 2019). Thus, the critical ecosystem for generating emerging technologies and businesses, where all parties will facilitate the development processes to nurture and grow an emerging industry (Ma et al., 2018).

Disruption literature tends to focus on established ecosystems (Beltagui et al., 2020), and the combination of disruptive innovation and ecosystem literature brings the paradox to companies that insert disruptions and interrupt the dynamics of an existing ecosystem, as they need support from historic operators to survive and grow (Ozalp et al., 2018; Palmié et al., 2019). Thus, technological disruption is seen at the ecosystem level, where the coevolutionary process can unite the different actors around the exploitation of disruption opportunities (Ansari et al., 2016; Zalan & Toufaily, 2017). Thus, through the dynamics of cooperation and competition, the ecosystem presents disruptors with the need to sew their value networks to emphasise the necessary changes for future growth (Anagnostopoulos, 2018; Sandström, 2016).

The interdependence of ecosystem members under coevolutionary processes is the primary driver of ecosystem development (Dedehayir et al., 2017). The value network allows the evolution of the business ecosystem as a habitat for productive interactions (Ma et al., 2018), a focal platform that incorporates mechanisms for creating and appropriating value (Beltagui et al., 2020). Thus, disruption requires an ecosystem developed to support innovation and an ecosystem that develops disruptive innovation that grows around that innovation. Therefore, interruption requires understanding the relationships that unite ecosystem actors, where competition is increasingly taking place, not between companies, but between platforms and ecosystems (Beltagui et al., 2020; Palmié et al., 2019; Sandström, 2016). Disruption will disrupt traditional models (Ansari et al., 2016), and the disruptors need to unite a new ecosystem around disruptive innovation to gain access to complementary resources from those responsible for the ecosystem they disturb (Kumaraswamy et al., 2018).

Like the technological transition, Ozalp et al. (2018) present the transition from video game platforms. During the transition from 2D to 3D graphics technologies, 3D technology offered new game development add-ons and created higher development costs for developers. When working with next-generation technologies, complementors could not apply the knowledge learned from the previous generation, requiring new investments and experiences to meet consumer expectations. 3D video game technology had expanded the technological limits of game development, where the learning curve was one of the most disturbing difficulties. The entire ecosystem was affected during the technological transition on video game platforms, disrupting existing platforms, breaking the links established with their complementors and limiting the high-quality production necessary for the next-generation platform to succeed. This paradox of technological insertion can occur even if the new technology is inserted by historical operators, being necessary for successfully managing the technological transition since the complements are essential for the platform's network effect and consequent success.

3.2.1. Impulse Forces of the Ecosystem

The ecosystem unification depends upon the forces that drive the necessary change. Forces such as economic or market crises (Anagnostopoulos, 2018; Bers et al., 2012; Lee & Shin, 2018), competition between companies, environmental pressures, changes in social patterns, user behaviour and governance pressures on public demand (Chan & Fung, 2016; Ma et al., 2018; Nicolai & Faucheux, 2015), can alter the development and urgency of disruption. By definition, disruptions are not in line with existing legislation and regulations designed to the modus operandi of that ecosystem (Chan & Fung, 2016).

It is usual for innovation to happen before regulation (Lee & Shin, 2018; Zalan & Toufaily, 2017), and it is necessary to break with traditional structures (Salvador et al., 2019). Thus, diverse forces that shape the trajectory of disruption and can drive or inhibit the evolution of an ecosystem permeate the regulatory environment. Traditional legislation restricts the development of disruptions and the evolution of ecosystems, where historic operators use to protect existing markets with barriers to entry of new technologies (Tham, 2016; Zalan & Toufaily, 2017). The trajectory of change brought about by disruptions is the challenge of bringing together the technology, the market and the regulations to facilitate the development of new network structures (Nicolai & Faucheux, 2015).

Environmental pressures are another critical factor impacting ecosystems and economic and political disruptions (Chan & Fung, 2016). It is possible to achieve a sustainable transformation between the disruption and the ecosystem as a co-evolution mechanism. Trends such as collaborative consumption, shared economy, green economy, low carbon economy, in addition to pressures for more sustainable organisational practices, make these changes in supply and demand conditions an essential factor in driving disruptions and the evolution of ecosystems (Ma et al., 2018). Impulses for sustainable regulations, technologies, and markets can positively correlate with the solutions provided by disruptions. Nicolai and Faucheux (2015) address the challenge of eco-mobility in bringing together the technology, the market and the regulations, where evolution in the governance process is expected, with the emergence of new pressure groups and changes in patterns of influence.

The social environment also plays an essential role in spreading disruption in the market (Bers et al., 2012). Many of the disruptions start with a focus on a group of unconventional users, separate from the markets traditionally served by incumbent operators (Anagnostopoulos, 2018; Christensen et al., 2018). Therefore, while certain user groups are reluctant to adopt disruptive innovation (Palmié et al., 2019), early adopters of disruption are essential drivers for the growth of other users (Lee & Shin, 2018). Another essential role of the social environment is public opinion favouring disruption as a driver of social acceptance (Bers et al., 2012). The challenge may lie in effective behavioural changes (Tham, 2016). Thus, innovative companies must create a condition to influence and shape social demand during the pioneering demonstration phase, forming the future demands of society in general (Nicolai & Faucheux, 2015).

Another distinguishing feature is the technological support environment where the ecosystem is embedded. Technology developers create a favourable environment for ecosystem development, where the supporting technology environment provides the basis for reconfiguring disruption (Lee & Shin, 2018; Salvador et al., 2019). New actors with specialised technologies build their position in the ecosystem's dimension based on the new technology presented. This encounter between traditional technology and disruption creates new spaces for cooperation and coordination in the production flow (Salvador et al., 2019). Many disruptors are based on new technologies, being a challenge to integrate into the incumbent operators existing systems (Lee & Shin, 2018).

Lee and Shin (2018) pointed to fintech as a disruptive innovation capable of shaking traditional financial markets. Their study identified five elements of the fintech ecosystem: the fintech, driving the phenomenon of financial services disaggregation in a way that is disturbing for banks; technology developers, providing digital platforms; governments, providing a regulatory environment that may be favourable to fintech companies; financial customers, the first adopters of the technology; traditional financial institutions, having competitive advantages in economies of scale and resources, and being able to collaborate with fintech companies. These elements contribute to innovation, stimulate the economy, facilitate collaboration and competition in the financial sector, and ultimately benefit consumers in the financial sector. As regulatory changes occur after industry innovation, fintech needs to be aware of the possible changes that can impact them and find ways to deal with these changes.

3.3. Business Models

Business models are a set of procedures and principles of value creation (Nicolai & Faucheux, 2015; Salvador et al., 2019) where technologies and business models are integral parts of the same projection to position innovations in a disruptive way (Christensen et al., 2018). Thus, in an organisation's business model, all components, technologies, and business design intertwine and complement each other (Rabin et al., 2019).

Operators located in a value ecology cannot disconnect their strategy from the ecosystem's needs, as their destiny tangles with the ecology's success as a whole (Bers et al., 2012). Faced with a disruption that can shake the entire ecosystem (Christensen et al., 2018), the company must operate as an adaptive, highly changeable, and complex system, capable of responding to changes, opportunities, and threats arising from the ecology itself. Thus, disruptive disruptions cannot be fully realised on their own and are embedded in an ecology of interdependent value from ecosystem actors and must be evaluated concerning the companies' business model (Bers et al., 2012; Christensen et al., 2018; Rabin et al., 2019).

Tham (2016) presents two cases showing the impact of the business model on disruption and the ecosystem: AirBnB and Uber. The cases in Singapore and Australia point to technology's role as a mediator of the smart tourism ecosystem. As such, the ease of transacting an AirBnB or Uber experience becomes commonplace. Within the distinct characteristics of each company in each of the regions, the sharing economy, disruptive innovation in tourism, and the highly interactive tourism ecosystem structure, were able to transform the tourism scenario.

Rabin et al. (2019) presented open education compared to traditional higher education. Disruptive digital innovation in the higher education sector fuels speculation about current and future higher education business models. The main narrative is interdependence and mutual innovation. Traditional higher education institutions have a teaching structure, syllabus, and other learning materials. Meanwhile, open education institutions, which are dependent on the resources of traditional universities, bring access to digital tools. Thus, those organisations will form a mutually dependent ecosystem where digital innovation is an essential mechanism for change, constituting a different business model for the educational system.

3.3.1. Innovation Flows

In the perspective of closing innovation within the company's walls for the development and exploitation of technologies and markets, problems such as lack of regulation, reservations by new entrants, opportunistic behaviour by operators can intensify competition among technologies in the markets (Chan & Fung, 2016; Zalan & Toufaily, 2017). When the most advanced disruption process creates threats, the company may return to a closed exploitation model. Thus, the ecosystem can develop exploration opportunities for closed and open models or even mixed exploration models (Cozzolino et al., 2018).

Opposed to a traditional closed business model, in the open models, companies can benefit from opening their technological developments to the entire ecosystem, even if this includes competitors (Rabin et al., 2019). In the open model, the availability of disruptive technologies offers new ways of creating and capturing value for historic operators (Cozzolino et al., 2018). Historical operators can take advantage of the fast ecosystem of new operators to accelerate the development of ideas and markets and position themselves as facilitators of technology. New operators can benefit from the assets and resources of historic operators and can also contribute to their innovation. The collaboration and partnership between incumbents and new entrants respond to a potential interruption through the complementarity of capabilities (Rabin et al., 2019; Tham, 2016; Zalan & Toufaily, 2017).

Through the strategic alignment of ecosystem partners, the collaboration between historic operators and new operators can create new value within the ecosystem and accelerate innovation (Zalan & Toufaily, 2017). In this way, an ecosystem operator can benefit from involvement with other actors to ensure the adoption of new technology (Beltagui et al., 2020). The disruptive change can alter competition, cooperation, and coopetition (Ansari et al., 2016). In the same way that disruption can reduce the value of incumbent operators (Sandström, 2016), disruption can offer benefits to members of the ecosystem built a coopetitive processes through flexible and inclusive processes, in search of synergy between incumbents, new entrants, regulators and the general public (Anagnostopoulos, 2018).

Regarding disruption, open business models, and market coopetition, Cozzolino et al. (2018) analysed the case of the Italian publisher GEDI from 1997 to 2017, reacting to the advent of the Internet and the emergence of new business models in the sector. The study showed two forces in the disruptive process: the initial advent of disruptive technologies and new business models by disruptors. The internet and related digital tools represented disruptive technologies, where GEDI opted for an open business model in its online projects while opting for a more closed model in most new offline projects. Publishers used their newsrooms and journalists to create value for readers while using complementary assets such as the printing, distribution, and sales process to capture value. GEDI has formed alliances with disruptive platforms and other publishers to share common knowledge against disruptive platforms online. The new open business model employed a mix of internal and external knowledge to create value and used platform-based strategies to capture value.

Finally, Ansari et al. (2015) document the relationship between incumbents and new entrants in the case of TiVo. The new technology has fundamentally transformed the display of programming and relationships within the ecosystem of the television industry. The TiVo service allowed viewers to watch what they wanted at the time they wanted. TiVo was a platform that could break the traditional television broadcasting model and in all the relationships and agreements that this existing model implied. TiVo faced coopetitive tensions because it was perceived as a disturbing force by the existing ecosystem. TiVo had to create relationships with television channels with advertisers while creating a new value for users. TiVo and its relational positioning in the ecosystem have evolved and have formed collaborative ventures with owners to highlight the potential of their innovation.

4. Integrating Theories

Disruptive innovation (Christensen, 1997; Christensen et al., 2018) has the potential to transform the entire ecosystem (Adner, 2012, 2017; Ansari et al., 2016), and it is up to the actors to co-evolve through the business models (Chesbrough, 2003; Rabin et al., 2019). Disruptions imply an appropriate support ecosystem (Beltagui et al., 2020) to develop and evaluate the disruption against the business model of the companies and ecosystems (Palmié et al., 2019).

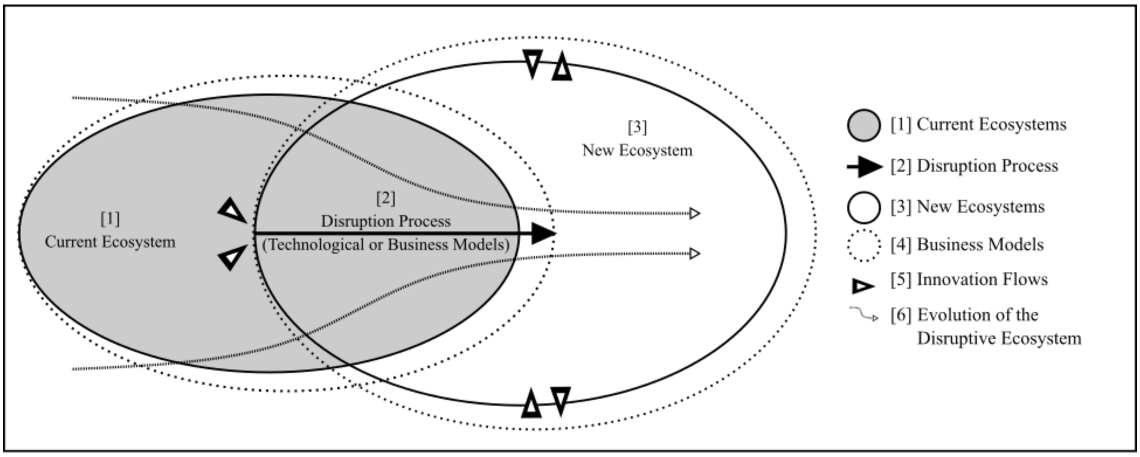
The concept of creative destruction implies the arrival of new technology and the consequent destruction of existing technology as a tool for market evolution (Chan & Fung, 2016; Dedehayir et al., 2017). Thus, developing a disruption implies a rupture with the existing technology ecosystem, integrating new ways of creating value (Beltagui et al., 2020; Nicolai & Faucheux, 2015).

Business models and disruptive innovations create different markets and present radically different challenges for companies (Markides, 2006). Viewed from the perspective of an innovation ecosystem, the business model considers the technological, commercial, political, and strategic interdependencies among ecosystem actors (Nicolai & Faucheux, 2015).

Companies must direct their strategies to the value ecology of the ecosystem, so they can participate in the innovation process but no longer possess it (Bers et al., 2012; Moore, 1993). A collaborative and coopetitive process will create new value within the ecosystem and accelerate innovation where the relevance of all components of the ecosystem will increase due to the interconnected nature of technologies and strategies (Granstrand & Holgersson, 2020; Zalan & Toufaily, 2017). Thus, in the face of disruptive innovation within an ecosystem, the business model becomes an essential tool for the co-evolution of business strategies (Christensen et al., 2018; Nicolai & Faucheux, 2015; Rabin et al., 2019).

Ecosystem theory shows that disruptive innovation is only possible when the entire ecosystem is considered (Williams, 2014), and continuous innovation guides ecosystem co-evolution over time (Hou & Shi, 2020). In this sense, the disruption breaks an existing ecosystem and forms a new one, involving characteristics of the new and the current ecosystem through disruption. Hence, this study proposes a theoretical framework (Figure 1) to illustrate the confluence of these two theories through a Disruptive Ecosystem.

Figure 1 - Theoretical Evolution of the Disruptive Ecosystem Framework.



Source: Developed by the authors.

Figure 1 shows that in an existing ecosystem [1] (Granstrand & Holgersson, 2020; Moore, 1993; Palmié et al., 2019) when a disruption process [2] occurs, from a technology or business model innovation (Bower & Christensen, 1995; Christensen et al., 2002, 2018), it can suffer from creative destruction (Dedehayir et al., 2017; Nicolai & Faucheux, 2015; Schumpeter, 1942) allowing a new ecosystem to thrive [3] grounded on the new technology with its business model (Palmié et al., 2019) and proper value network (Adner & Kapoor, 2016; Brandenburger & Nalebuff, 1996; Ma et al., 2018). External forces, such as supporting technologies, the regulatory environment, and environmental and social pressures, can be barriers or impellers of the innovations. Some elements interact within the ecosystem being replaced until the end of the disruption process. Other elements of the ecosystem that is being shaken coexist with the new technology and the new business model, migrating to the new ecosystem.

The business models [4] overlap the ecosystem since they encompass existing technologies and actors in the new model. During the disruption process, existing and new technologies or business models coexist in the market. Business models are sometimes composed of elements from inside and outside the ecosystem, with blurred boundaries. The business models are together with the entire ecosystem and link the actors and technologies of the ecosystem in the entire disruption process. Actors in the existing ecosystem can use innovation and become part of the disruption or the new ecosystem can strengthen from the existing ecosystem to boost disruption. The disruption can come from one of the actors in the value network or new ecosystem actors (Chan & Fung, 2016; Christensen et al., 2018; Dedehayir et al., 2017; Tham, 2016).

This proposal considers existing subsystems as interconnected parts within a larger ecosystem (Adner & Kapoor, 2016; Granstrand & Holgersson, 2020; Palmié et al., 2019) and being part of integrated business models that surround the entire ecosystem. These subsystems can be constituted by suppliers and development partners of complementary technologies or even the infrastructure necessary for the development of the ecosystem and can be partially or totally immersed within the main ecosystem. Other parallel subsystems (Nicolai & Faucheux, 2015) can also break out with disruption, where technology creates distinct markets based on disruptive innovation. Furthermore, the ecosystem is complemented by innovation flows [5] directed towards the ecosystem and disruption (Cozzolino et al., 2018; Rabin et al., 2019). The flows of an open business model are part of the surrounding environments, which can interact with disruption and cause and change the ecosystem that permeates the ecosystem and contemplates elements that are inside and outside the current ecosystem. The flows of open business model lead the relationships of ecosystem players and allow the entry of new actors in the ecosystem (Anagnostopoulos, 2018; Ansari et al., 2016; Sandström, 2016).

This study also proposes the concept of Evolution of the Disruptive Ecosystem [6], where historic operators need to evolve to the disruption that occurs, and new operators to the existing environment. This evolution process is due to the destruction of existing technologies and business models. The ecosystem must evolve to the new paradigm of environmental, social, regulatory, technological, competition, and collaboration pressures to develop the new ecosystem. In this process of evolution of the ecosystem, the idea of disruptive innovation reigns (Christensen, 1997, 2006; Christensen et al., 2018), with characteristics of the old and new actors, and with characteristics of the old and new technologies and business models, where companies that do not adapt to the evolving environment suffer disruption and cease to exist.

Assuming that disruption only happens when one technology supersedes the other, affecting the ecosystem, disruptive innovation transforms the ecosystem, both by creating new actors or adapting the existing ones. Unlike radical innovation that destroys a particular technology pattern and its ecosystem, a disruption can embrace growth with new technologies and business models to evolve into a new ecosystem with the flows of current resources of the incumbents' historical operators and new capabilities.

Thus, this study understands disruption as a tool for the destruction and creation of ecosystems reconfiguring the existing value. Innovations internal or external to the ecosystem can unsettle the system until a new disruption occurs. Within this changing environment, the actors influence each other in a coopetitive way and co-evolve the innovative ecosystem, building and developing their technologies and business models in a complementary way.

5. Conclusions

This study started with an integrative literature review to investigate how disruptive innovation can affect established industries and trigger the development of a new innovation ecosystem. Three essential topics in this dynamic arise: disruption, the constitution of the ecosystem, and the involved business models.

Disruption plays a role in changing the established technological paradigm or business models (Christensen et al., 2018). Coupled with the concept of creative destruction (Dedehayir et al., 2017; Nicolai & Faucheux, 2015), disruption can transform the existing ecosystem (Ansari et al., 2016; Rabin et al., 2019; Sandström, 2016) and generate new markets (Ansari et al., 2016; Chan & Fung, 2016). Historical and new operators coexist, coopete, and co-evolve in this complex ecosystem.

Interconnected and interdependent ecosystems (Ansari et al., 2016; Rabin et al., 2019; Sandström, 2016) create dependent value among organisations within the ecosystem (Ansari et al., 2016; Yaghmaie & Vanhaverbeke, 2019). Technologies and business models complement this value network (Kumaraswamy et al., 2018), where regulatory, environmental (ecological), social, and supporting technology forces can stop or drive disruption within an ecosystem. Through this dynamic, the ecosystem tailors its value networks (Adner & Lieberman, 2021; Ansari et al., 2016; Sandström, 2016), permeated by forces that prevent or drive disruption within the environment but emphasise the necessary changes for future growth. Openings within the innovative ecosystem benefit the entire ecosystem (Rabin et al., 2019) by creating and capturing value among all actors (Cozzolino et al., 2018). Ecosystem actors share an interconnected value ecology strategy to pursue the development of the entire ecosystem (Bers et al., 2012).

This study adds to the disruptive innovation and ecosystems' research flow to deepen the comprehension of how disruption affects the development of a new ecosystem. Business models build the value network around disruption and its development within the ecosystem. Another contribution is the concept of evolution to the disruptive ecosystem, where actors need to adapt to the evolution of the environment. This process is forced by the destruction of existing technologies and business models, and the disruptive ecosystem embraces growth with new technologies and business models to evolve into a new ecosystem. Thus, these findings provide new avenues for studies on disruptive innovations and ecosystems.

There are limitations, mostly related to using two scientific databases for the integrative literature review. Even though both databases are relevant, the following studies can use additional sources to endorse the results. This paper allows a research agenda to deepen the understanding of how the disruption impacts new ecosystems. As a suggestion, case studies could use the proposed framework to understand the construction of markets through ecosystemic disruption. Further studies could explore developing (disruptive) technologies and their potential to impact existing ecosystems.

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ARTICLE 2 – DISRUPTION IN THE TRANSPORTATION MOBILITY ECOSYSTEM: AN ANALYSIS OF ORGANIZATIONAL OBJETIVES AND THE TRANSITION TO SUSTAINABLE TECHNOLOGIES

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Decide what you stand for. And then stand for it all the time.
(Clayton M. Christensen).

DISRUPTION IN THE TRANSPORTAION MOBILITY ECOSYSTEM: AN ANALYSIS OF ORGANIZATIONAL OBJETIVES AND THE TRANSITION TO SUSTAINABLE TECHNOLOGIES

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Abstract

Purpose: To analyze how potentially disruptive innovations can change the current technological transportation mobility ecosystem focusing on a sustainable perspective.

Design/methodology/approach: In this article, we apply content analysis on the mission, vision and values of transportation mobility companies of internal combustion engines (ICEs), electric vehicles (EVs), autonomous vehicles (AVs) and electric vertical take-off and electronic landing (eVTOLs) focused on engagement of companies in the sustainable practices of the Sustainable Development Goals (SDG).

Findings: The results show the development of new technological perspectives, transportation mobility moves towards sustainable technologies through the electrification and automation of vehicles, in addition to a possible aerial scenario in transportation mobility.

Originality: This study argues that it is necessary to change the current paradigm, focused on ICE, the focus of the automotive sector. It is assumed that the strategies and objectives designed and applied are based on technology development and reflect the innovation ecosystem's business model. Therefore, the originality of this study lies in exploring the transition of the value proposition of the transportation mobility ecosystem based on the proposition of new potentially disruptive technologies.

Research limitations/implications: This research has limitations in the number of companies and data collected, limited to the information provided by companies. This research also brings a theoretical contribution to the literature on disruptions where new technologies emerge to impact the current mobility ecosystem. This study can also contribute to SDG implementation. This analysis allows us to understand how firms in this sector adapt to sustainable trends and the change in the transportation mobility industry for companies to seek cleaner technologies.

Practical/managerial implications: As managerial contribution, it allows managers to reflect on sustainability issues and the adequacy of SDGs for disruptive changes in ecosystems. This change is an opportunity to position in the new ecosystem that is born based on disruptions.

Keywords: Innovation Ecosystem; Sustainable Development Goals; SDG; Mission; Vision; Values; Objectives; Business Strategy.

1. Introduction

Institutional pressures have driven companies to produce innovations for sustainable development (Jordão, 2022; Kivimaa & Kern, 2016; Nidumolu et al., 2009). As innovation is a force that drives change (Kastrinos & Weber, 2020), new technological standards are used as means to achieve sustainability. In this path, the United Nations (UN), by establishing the global initiative of the Sustainable Performance Goals (SDGs), proposed a universal agenda on economic, social, and environmental needs (Kates et al., 2012; UN, 2020; United Nations, 2021), placing sustainable technological innovation as a disruptive factor in the current production industry.

By considering that disruption has the potential to reshape industries and ecosystems (Kumaraswamy et al., 2018; Oghazi et al., 2022; Silva & Grützmann, 2022), the automotive sector has been reconfiguring itself according to the needs of the innovative context of the transportation mobility sector. Due to the presence of more sustainable technological innovations (EVs, AVs and eVTOLs), the transportation mobility ecosystem has been instigated to transform the way of getting around. However, discussions on mobility, innovation, and sustainability (SDGs) are still nascent and inconclusive and have several theoretical and practical gaps.

Based on the studies by Ali et al. (2018), Hák et al. (2016), Imaz and Eizagirre (2020), Kastrinos and Weber (2020), Leal Filho et al. (2017) and Ordonez-Ponce et al. (2021), we find that little evidence addresses the relationship between firms' strategic practices with the SDGs. These authors have argued that the implementation and execution of practices related to the SDGs are restricted to the business scope, and few theoretical efforts seek to concretize the performance in the face of sustainable innovation. This gap becomes stronger when considering the transformation of the ecosystem. Therefore, there is little research on how changing sustainable technologies influence the ecosystem via strategies, goals, and mechanisms of value capture and creation (Holgersson et al., 2022; Njoroge et al., 2019; Yaghmaie & Vanhaverbeke, 2019) of a given sector, in this case, represented by transportation mobility. We aim in this study to understand the following problem: how do automotive companies present their sustainable strategic practices (SDGs) in the face of the changing technological context of transportation mobility?

To answer this question, considering the strategic transformations of ICE companies in the EVs, AVs and eVTOLs technologies, this study aims to analyze how potentially disruptive innovations can change the current technological transportation mobility ecosystem focusing on a sustainable perspective. As a thesis, we argue that institutional pressures lead firms to act strategically via sustainable technology, causing ecosystem transformation. Through the Forbes (2020) list of the top 1,000 companies in the market, we analyze the missions, visions, and values of companies that develop new technologies. As a result, we found that companies review their strategies (mission, vision, and values) encompassing the SDGs. This review impacts the ecosystem, aligning it with innovative practices such as the emergence of EVs, AVs, and eVTOLs.

The contribution of this research is threefold. First, in addition to contributing theoretically to the gap mentioned above, we confirm that innovations are means for companies to engage in sustainable practices to achieve their strategic goals (Imaz & Eizagirre, 2020; Ordonez-Ponce et al., 2021). We also confirm that the best strategies, goals, and pursuit of value help orchestrate ecosystem transformation (Holgersson et al., 2022; Yaghmaie & Vanhaverbeke, 2019). Second, managerially, we provide insights for managers interested in implementing the SDGs, enabling them to develop innovative actions that can impact their ecosystem. Finally, socially and economically, it is hoped that the results of this study can be used by managers, analysts, policymakers, and other decision-makers so that public policies can subsidize and promote the economic growth of innovative ecosystems and sustainable practices in the long term.

Finally, this article is structured with the theoretical framework presented in topic 2 and the research methodology presented in topic 3. Topic 4 presents the Results and Discussion with the literature. In topic 5 we present the contributions to the literature and practice. Furthermore, in topic 6 we present the Conclusions of the research.

2. Theorectical Framework

2.1. Evolution of Technology Transport Modes in the Word

Currently, about 1.3 billion vehicles are powered by combustion technology (OICA, 2015). However, a small percentage of the world's fleet comprises vehicles from alternative sources (Yan et al., 2018). Introducing disruptive technologies, such as EVs, AVs and eVTOLs, can trigger a transformation in the automotive industry (Dijk et al., 2016; Skeete, 2018). Since the late 2000s, vehicle electrification technology has brought different perspectives to transport modes and impacted the automotive industry. Forecasts indicate that 2% of the vehicle fleet will be composed of electric propulsion sources until 2025 and will reach 31% by 2040 (Statista, 2020). EVs have advantages over transport costs (Heidrich et al., 2017) and have the potential to reduce global pollutant emissions (Alghoul et al., 2018). The disruptive technology of AVs (Skeete, 2018) allows safer transport for any individual (Fagnant & Kockelman, 2015; Lutin et al., 2013), lower costs (Bösch et al., 2016; Meyer et al., 2017), more sustainable travel (Wadud & Anable, 2016b), bringing new possibilities to transport (Fagnant & Kockelman, 2015). AVs facilitate vehicle sharing (Krueger et al., 2016; Merfeld et al., 2019), can reduce the total fleet on the roads (Bösch et al., 2016) and reduce congestion (Fagnant & Kockelman, 2014).

Despite EVs and AVs being in their infancy, eVTOLs emerge as a possible disruption in the transport market. EVTOLs use aerial space, relieving ground transport (Curtis, 2019; Pradeep & Wei, 2019; Uber Elevate, 2016). Among automotive technologies, eVTOLs are on the farthest horizon for adoption but could advance as the EV and AV markets grow. While traditional transport undermines environmental, social and economic sustainability (López et al., 2019), EVs, AVs and eVTOLs emerge as sustainable businesses that reflect corporate values and culture, can be a significant tool in driving change, and key requirements for thriving business (Rosli et al., 2019). However, to consider the sustainable impact of alternative forms of transport, it is necessary to associate it with a broader discussion involving the needs of society. Therefore, the future of transportation mobility needs to be associated with discussions about SDGs.

2.2. Sustainable Development Goals (SDGs)

Organizations and governments must develop strategies to support and drive sustainability through innovation (Jordão, 2022). Technological innovations are a business opportunity for sustainable development (Constantinescu & Frone, 2014; Ordonez-Ponce et al., 2021). From a sustainability perspective, the ability to innovate may represent a necessary business capability and is related to sustainable growth and long-term profitability (Njoroge et al., 2019). Concern for sustainable development emerged in the context of environmental issues (UN, 1982). In September 2000, world leaders gathered at the UN Headquarters in New York and proposed eight Millennium Development Goals (MDGs), which were adopted by 189 nations (Griggs et al., 2014). With a 15-year term, the MDGs aimed to improve the lives of the world's poor and had considerable success, mainly as it managed to halve the number of people living on less than $1.25 a day. This sustainable development plan gained public and political support from international agencies and foundations (Vandemoortele, 2011).

Since then, several worldwide discussions have provided theoretical and practical mechanisms for the development of nations in order to reconcile the contrasting paradigms: continuing economic growth and efficient protection of the environment and natural resources (Hák et al., 2016). This sustainable development plan gained public and political support from international agencies and foundations The UN Rio+20 conference happened in 2012, in which the 2030 Agenda for Sustainable Development was proposed (Gupta & Vegelin, 2016). The SDG declares universal and applicable goals to all nations by 2030 (Griggs et al., 2014; Hák et al., 2016). The UN has defined 17 SDGs to achieve universal actions to protect the planet, minimize poverty, and ensure people enjoy peace and prosperity (Kates et al., 2012). As a corporate tool, the SDGs help maintains organizations' social responsibility (Harris, 2000). The SDGs encourage "action over the next fifteen years in areas of critical importance for humanity and the planet" (United Nations, 2021).

The SDGs aim to provide a policy-making framework for all countries (Horner, 2019). They pursue the elimination of poverty, the adoption of a sustainable lifestyle, and a stable and resilient planetary life support system (Griggs et al., 2014; Leal Filho et al., 2017). Table 1 presents the seventeen SDGs, for which 169 targets and 303 indicators. Goals 1 to 6 are based on the central agenda, while the other goals, 7 to 17, reflect new paths to be taken (Hák et al., 2016; UN, 2020).

Table 1. 17 Sustainable Development Goals.

SDG	Description
1 – No Poverty	End poverty in all its forms everywhere.
2 – Zero Hunger	End hunger, achieve food security and improve nutrition and promote sustainable agriculture.
3 – Good Health and Well-being	Ensure healthy lives and promote well-being for everyone at all ages.
4 – Quality Education	Ensure quality education for everyone and at all ages.
5 – Gender Equality	Achieve gender equality and empower women and girls.
6 – Clean Water and Sanitation	Ensure access to water and sanitation for all.
7 – Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy.
8 – Decent Work and Economic Growth	Promote inclusive and sustainable economic growth, employment and decent work.
9 – Industry, Innovation and Infrastructure	Build resilient infrastructure, promote sustainable industrialization and foster innovation.
10 – Reducing Inequality	Reduce inequality within and between countries.
11 – Sustainable Cities and Communities	Make cities inclusive, safe, resilient and sustainable.
12 – Responsible Consumption and Production	Ensure sustainable consumption and production patterns.
13 – Climate Action	Take urgent action to combat climate change and its impacts.
14 – Life Below Water	Conserve and sustainably use oceans, seas and marine resources.
15 – Life On Land	Sustainable management of forests, combating desertification, halting and reversing land and biodiversity degradation.
16 – Peace, Justice, and Strong Institutions	Promote just, peaceful and inclusive societies.
17 – Partnerships for the Goals	Revitalize the global partnership for sustainable development.

Source: Surana et al. (2020).

According to Kastrinos and Weber (2020), the 17 SDGs can be grouped into four categories: Innovation, Social Needs, Biosphere, and Governance. The Innovation area seeks to take advantage of strengths and mechanisms in search of change (SDG 4, 8, 9 and 11); Social Needs seek to meet people's needs to ensure a better life for everyone (SDG 1, 2, 3, 5, 6, 10, and

12); the Biosphere seeks to safeguard the planet to ensure the survival of all species (SDG 7, 13, 14, 15); and Governance seeks to join forces to establish conditions and manage the transition to a better world (SDG 16 and 17). This categorization allows for categorizing sustainable goals in an interdependent and overlapping way (Kastrinos & Weber, 2020). Since few studies and experiences safely demonstrate the interaction between the goals (Griggs et al., 2014).

In addition to the lack of integration between the SDGs themselves, which causes little synergy between the goals and results in a trade-off between socioeconomic development and global environmental sustainability, other points still need to be unveiled (Griggs et al., 2014). Gupta and Vegelin (2016) demonstrate the need for focus and measurability, as there is still no consensus on measuring current well-being and sustainability (Hák et al., 2016). Also, sustainability-driven innovation can drive private sector engagement toward the SDGs and transform companies' business models in the same direction (Imaz and Eizagirre, 2020). This transformation of companies' business models can transform innovation ecosystems (we will see below) and society, changing the hegemonic paradigm to a sustainable development paradigm (ICSU, 2020; Kastrinos and Weber, 2020; Leal Filho et al., 2017).

2.3. Development of the Innovations Ecosystem

Technology or business models are forces that can disrupt industries (Christensen et al., 2018; Kumaraswamy et al., 2018) and foster the building of innovation ecosystems (Adner, 2006, 2017). Ecosystems play a crucial role in emerging new technologies (Moore, 1993) and jointly create value that isolated firms could not create (Adner, 2006; Holgersson et al., 2022). The development of disruptive technologies becomes so costly and risky that firms join forces in complex innovation networks or ecosystems (Adner & Kapoor, 2010; Leten et al., 2013). Innovation ecosystems operate through an evolving set of actors, activities and artifacts, institutions, and relationships. The innovation ecosystem emphasizes collaboration, complementarity, and competition between actors around the development of innovations (Granstrand & Holgersson, 2020; Moore, 1993). As well as EVs, AVs, and eVTOLs technologies, ecosystem theory shows that disruptive innovation is only possible when the entire ecosystem is considered (Williams, 2014).

The co-evolutionary dynamics in an ecosystem allow a permanent exchange between actors and internal and external environments for continuous innovation (Hou & Shi, 2020; Silva & Grützmann, 2022). Ecosystem dynamics create a value network to establish disruptive innovations (Adner & Kapoor, 2016; Brandenburger & Nalebuff, 1996; Petzold et al., 2019). They can be instruments of change and restructuring of value chains for major social changes, such as the integration of electric or autonomous cars (Cozzolino et al., 2018; Yaghmaie & Vanhaverbeke, 2019).

The ecosystem, through its diversity of actors, works as a complement in the joint creation of value and its interdependence (Yaghmaie & Vanhaverbeke, 2019). The leader plays a central role in this architecture as it seeks to transform the market, re-establish industry standards and leverage the ecosystem (Berglund & Sandström, 2017; Dedehayir et al., 2017; Ozalp et al., 2018). For disruptors, the task is to unite a new ecosystem around disruptive innovation to gain access to complementary resources (Kumaraswamy et al., 2018). Disruption requires an ecosystem developed to support innovation (Beltagui et al., 2020) while the ecosystem develops and grows around disruption (Palmié et al., 2019).

3. Methods and Procedures

According on the article's objective, this study can be framed as qualitative and documentary. We followed the protocol developed by Ali et al. (2018), where the authors defined the operationalization strategy of the study and justified the inclusion and exclusion criteria of the documents to be analyzed. We, therefore, followed the same indication of the authors. This research was conducted in 2021.

Initially, to compose our research corpus, we used the Forbes (2020) list of the "world's largest public companies" as a criterion for the inclusion of companies in the research (internal validity). The justification for using this list was the methodology used by Forbes, which considered different variables for the classification of companies. Among them is sustainability, a key factor in the research. The Forbes site shows the 1,000 largest companies. We analyzed each of them to verify their development of products and technologies for the transportation mobility sector in ICEs, EVs, AVs and eVTOLs.

For the selection of companies, we established three exclusion criteria. First, the companies should have active websites. Second, they should develop/use at least one of the vehicle energy technologies. Third, they should clearly state their mission, vision, and values on their websites. We reasoned that mission, vision, and values are clear explications of organizations' strategy, sustainability, and innovation, as well as reflect their positioning vis-à-vis their ecosystem (Ali et al., 2018; Bart, 1998; Baumgartner, 2014; Campbell, 1991; Lynn & Akgu, 2001; Raynor, 1998; Waddock & Smith, 2015). We excluded all companies that did not fit these criteria from the survey. In the end, we obtained 40 companies as the final corpus of analysis.

For the analysis of the missions, visions, and values, we applied closed-grid content analysis. We applied Bardin's (2016) protocol, combining frequency and thematic techniques. The frequency technique accounted for some important indicators for the research (characterization of the corpus). On the other hand, the thematic technique aimed to identify categories related to the 17 SDGs. We used the Google search tool to search the sites, in addition to MS Excel® spreadsheets. In the spreadsheet, we entered information about the company name, the year it was founded, area of activity, global site, mission, vision and values, and types of technology. We emphasize that when entering the data into the spreadsheet, we repeatedly considered the companies that presented more than one technology for vehicles because these companies, in most cases, presented headquarters and subsidiaries with differentiated technology. We justified the repeated inclusion because we considered that this factor would not present biases for the result of the research.

In the operationalization of the analysis, we used the closed grid, composed of the 17 SDGs and the companies' missions, visions, and values. This way, we counted the number of companies according to the SDGs. We also aimed to establish analytical categories within each cell (matrix of the 17 SDGs by missions, visions, and values). To reduce the subjective interpretation of researchers (reliability and internal validity), we chose to apply triangulation by researchers (cross-checking). The operationalization of this triangulation occurred as follows: Initially, we developed three copies of the spreadsheet with the company's information. Each spreadsheet was sent to three different researchers. These researchers performed their analyses separately. Later, a meeting was scheduled with the three researchers and the other authors. We revisited all cases, considering the convergences and divergences in the analyses. All participants discussed the divergent cases, and a decision was made by complete consensus. We justify using this procedure because we consider it rich and detailed, reducing interpretation biases. With the classification of the companies according to the research objective, we proceeded to interpret the results against the literature (external validity). Finally, the choice of the literature base for this article was based on respected journals classified in the Web of Science and Scopus databases; and the main limitation of the work was in the search for information on the companies’ websites. Many sites were outdated, according to the products and technologies offered by the companies, or they were not active.

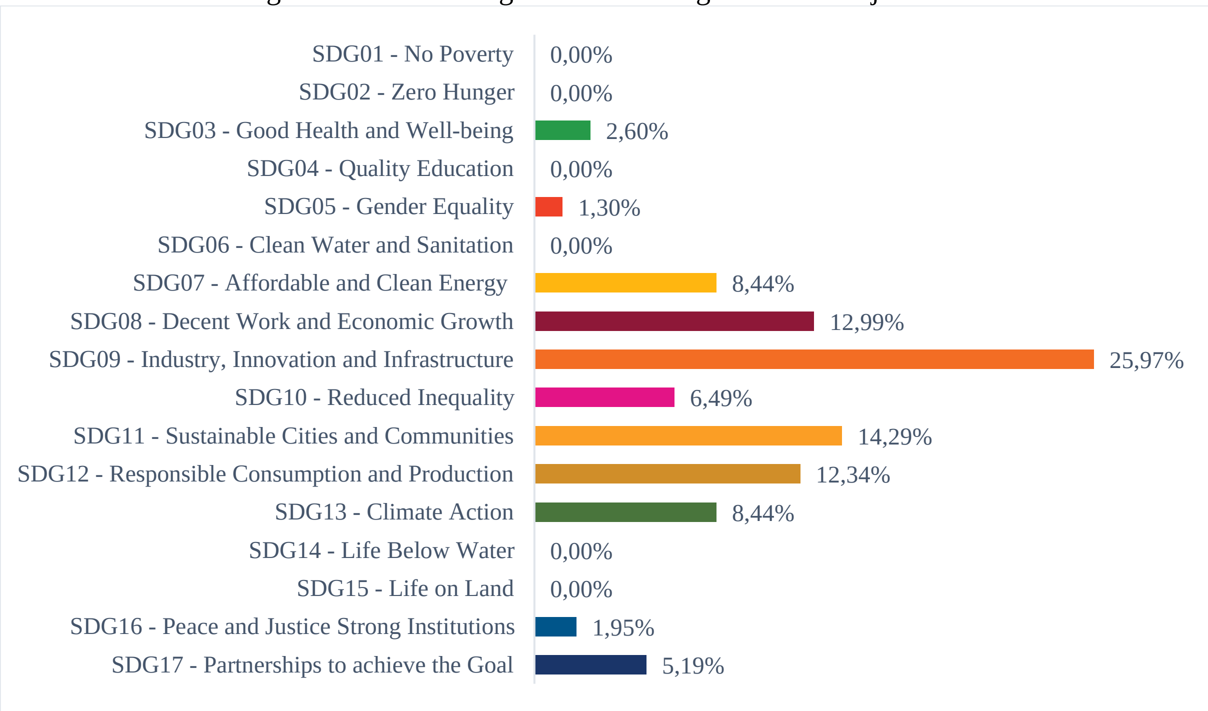
4. Results and Discussions

We present the analysis in four sections. The first analysis addresses the strategy present in organizations' missions, visions, and values considering the 17 SDGs. In the second section, we present the results within the model of Kastrinos and Weber (2020). In the third section, an analysis focused on the technological concentration of transportation vehicles. In contrast, the last part focuses on the organizations' strategy facing the technological transition of the transportation mobility ecosystem. In topic 5, we discuss the results with the literature.

4.1. Analysis of the SDGs

This section presents the counts of all citations from the SDGs organizations' missions, visions, and values. It is possible to verify which are the most outstanding of the 17 SDGs in the organizations' objectives, as established in Figure 1.

Figure 1 – Outstanding SDGs in the organizations' objectives.



Source: Research data.

In Figure 1, it is possible to see that most of the missions, visions and values point to the objectives of "industry, innovation and infrastructure" (25.97%), "sustainable cities and communities" (14.29%), "work decent and economic growth" (12.99%), and "sustainable production and consumption" (12.34%).

Meanwhile, other SDGs such as "climate action" (8.44%), "renewable and accessible energies" (8.44%), and "partnerships for the implementation of goals" (5.19%) are favorable goals for the transition of technology into more sustainable energies. On the other hand, the SDGs of "reducing inequality" (6.49%), "peace, justice, and effective institutions" (7.53%), and "gender equality" (1.30%) emphasize reductions in inequalities between countries in fairer societies and achieving equal opportunities for genders. It is possible to note that these objectives are not directly related to the core activities of organizations but are related to their corporate environments.

Other goals were less expressive or not found at all, such as "quality health" (2.60%), "quality education" (0.00%), "protecting terrestrial life" (0.00%), "eradicate poverty" (0.00%), "eradicate hunger" (0.00%), "drinking water and basic sanitation" (0.00%), and "protect marine life" (0.00%). Therefore, this result can be justified as they are not related to the core activities of the organizations studied. Therefore, such goals have characteristics such as promoting well-being, generating education, protecting forests, accessing food and sanitation, and conserving the oceans. This is general and little related to an organizational environment or developing new technologies and transportation mobility practices.

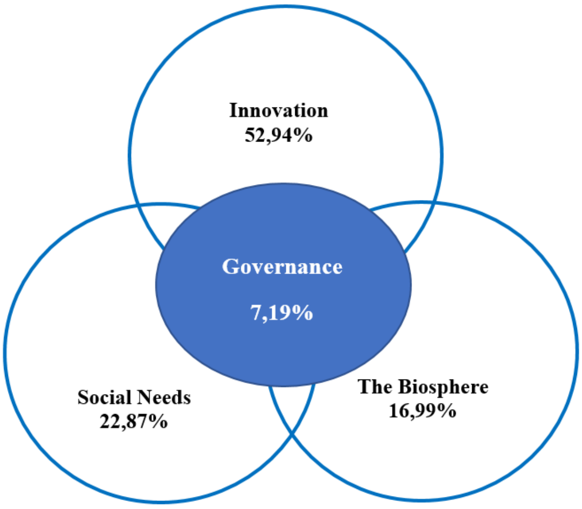
Concerning the SDGs in the organizations' objectives, we can associate the main goals (SDG09, SDG11, SDG08, SDG12) with the development of transportation mobility, which considers the evolution of technology to cleaner ones based on electricity (EVs, AVs, and eVTOLs). These structural changes for the replacement of ICE technology are, according to the current literature, where the new technologies can reduce global pollutant emissions and be sustainable in an environmental, social, and economic sense (Alghoul et al., 2018; Heidrich et al., 2017; López et al., 2019; Wadud & Anable, 2016a). It is important to highlight that the objective of "industry, innovation and infrastructure" was the only one found in the analysis of all the firms studied. This is at variance with the literature where there is an assumption that switching to new technology can lead to the loss of existing technologies and infrastructure (Bower & Christensen, 1995; Christensen et al., 2018; Markides, 2006), which prevents adherence mainly to the SDGs (Hausknost & Haas, 2019; Kastrinos & Weber, 2020). However, the companies studied correctly relate this change in the form of sustainable transfer of technological standards.

The SDGs are a stimulus for developing important areas for humanity and the planet (United Nations, 2021). Thus, it was possible to find a significant relationship between organizational strategies and ecosystem change aimed at developing a new type of industry, transportation development, and production and consumption patterns (SDG09, SDG11, SDG08, SDG12) that seek more sustainable economic development. In this sense, some researchers corroborate these ecosystem changes (Constantinescu & Frone, 2014; Hák et al., 2016; Jordão, 2022; Njoroge et al., 2019; Ordonez-Ponce et al., 2021) with greater concern about practices related to the SDGs with the development of a new, more sustainable market. This research found less effort in practices related to climate, energy, social and environmental actions. However, these objectives/activities are directly related to developing new markets. It is possible to understand that there is a concern with the innovative development of firms and with some characteristics of the environment that foster this ecosystem (Beltagui et al., 2020; Kastrinos & Weber, 2020; Kumaraswamy et al., 2018; Palmié et al., 2019; Silva & Grützmann, 2022).

4.2. Analysis of SDG Areas

Figure 2 illustrates how the SDGs fit into the four categories suggested by Kastrinos and Weber (2020). Here, all citations referring to the SDG were added and adjusted within the categories of innovation, social needs, biosphere, and governance. Innovation (52.94%) is about taking advantage of the forces and mechanisms of change, and it was the most common feature found in the firms' proposals. Because the analysis is from a perspective of technological development, from ICEs to EVs, AVs, and eVTOLs, the innovation factor becomes a constant purpose of the firms surveyed. Such characteristics can be found in firms outside the transportation mobility sector and develop innovations in vehicle automation, as in the IBM mission: "*Promote revolutionary innovations, explore the possibilities of the future*"; or in the strategy of firms transitioning from ICE technologies to EVs and AVs, in the case of Daimler: "*We are shaping the transformation of the automotive industry from a leadership position - in a way that is customer-focused, sustainable, innovative and commercially successful*".

Figure 2 – SDG Areas in Organizations.



Source: Research data.

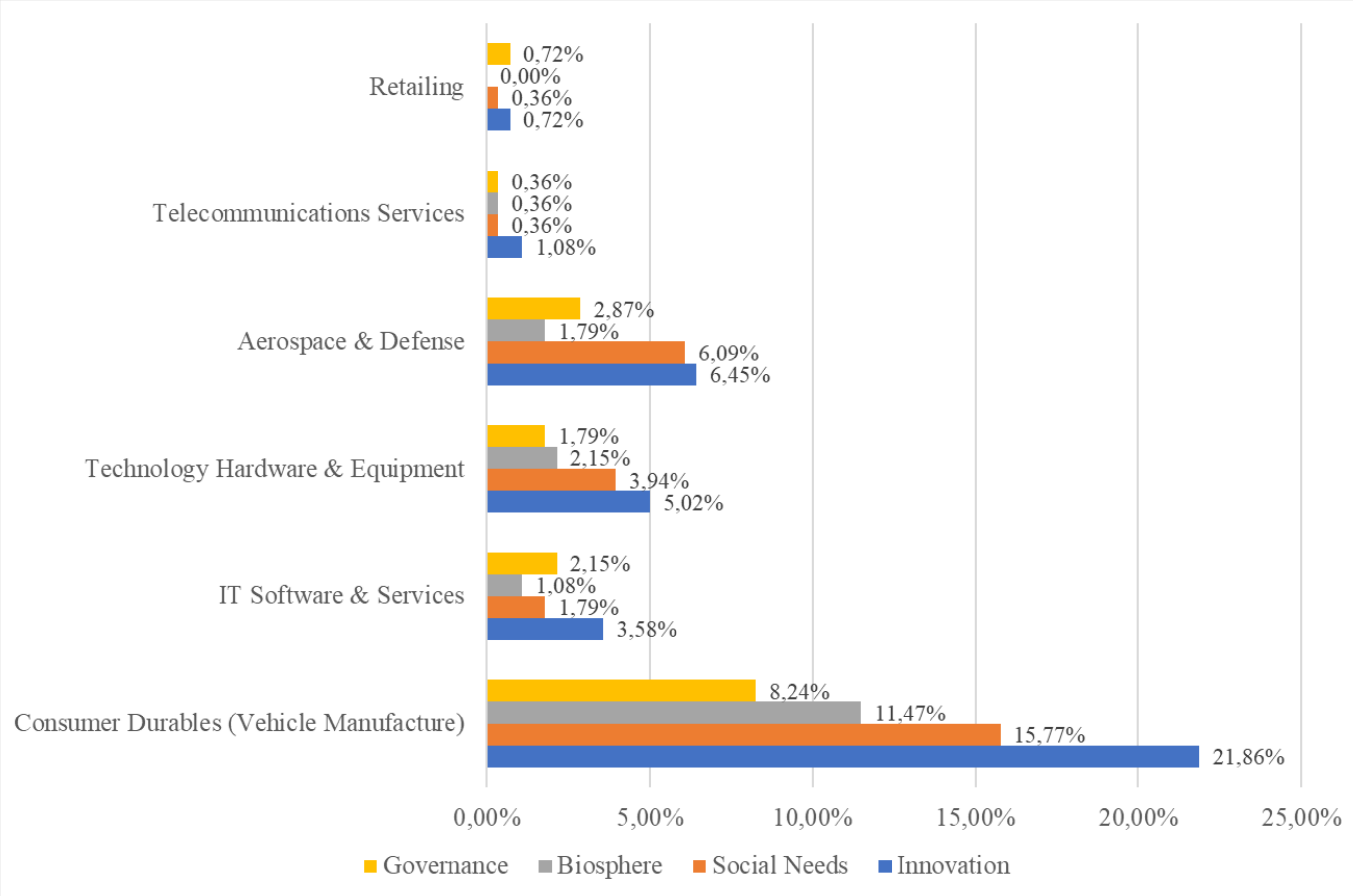
Social needs (22.87%) refer to meeting people's needs - therefore, as the focus of changing technologies tends to alter and develop different social patterns related to transportation mobility, organizations propose to carry out this change. As an example, the proposal by Kia Motors: "*Building a new future and fulfilling humanity's dreams, thinking creatively and facing challenges head-on*"; from Alphabet/Waymo: "*Waymo's mission is to* *make it safe and easy for people and things to get where they are going*”; and from Orange: “*We are working to ensure that our commitment to corporate and social responsibility has a positive impact on people, society and the planet*”; which shows the focus on social practices.

The biosphere (16.99%) is about safeguarding the planet. Despite the reduction of environmental impacts caused by the replacement of ICE technology by EVs, and many firms employ sustainability in their missions and strategies, protecting the planet is not the main focus of organizations. Therefore, it is focused on technological innovation and market change, as presented by Subaru: “*The preservation of our planet's ecosystem, the earth, the sky and nature, is extremely important to ensure the future sustainability of society and our organization*”.

Finally, governance (7.19%) is the smallest groups, with only two SDGs. Governance refers to the joining forces of organizations to generate conditions for change, which can be applied to changing the technological standard. Hyundai Motors exemplifies: "*Collaboration - We create synergy through a sense of "unity" that is fostered by mutual communication and cooperation within the company and with our business partners.*"

Finally, by separating the organizations analyzed by area of activity, Figure 3, it is possible to verify the predominance of categories in the areas of activity of the firms.

Figure 3 – Areas of the SDGs by area of expertise.



Source: Research data.

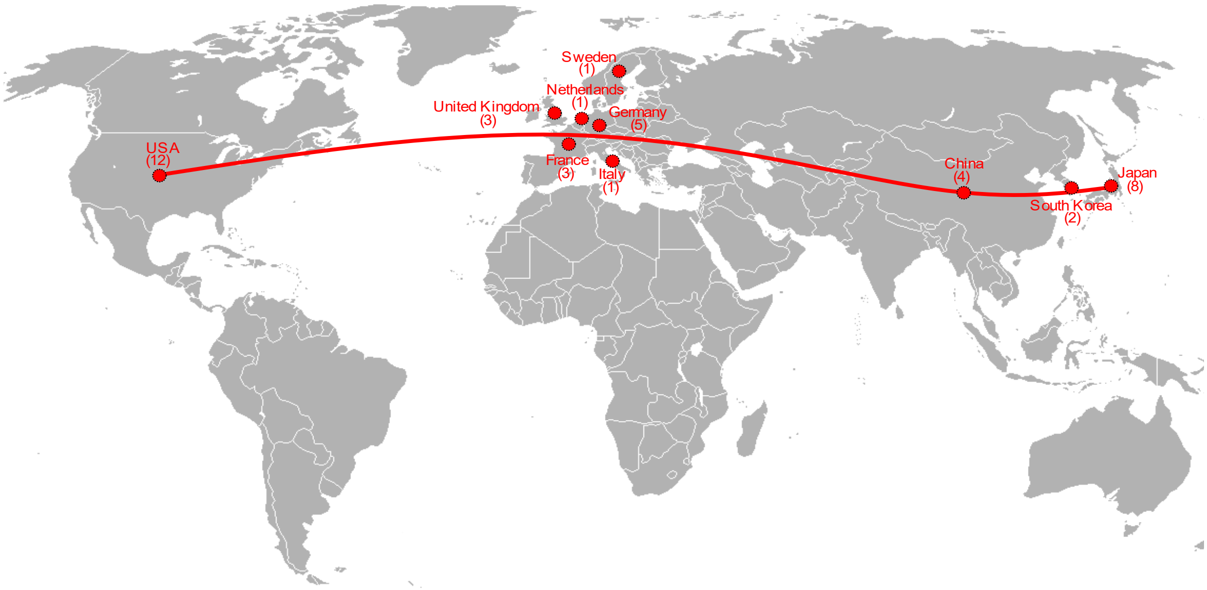
Overall, in all areas, innovation was predominant, followed by social needs. This result demonstrates that the proposed technological change for transportation mobility tends to impact social practices. Missions like Toyota: "*Toyota will lead the future mobility society, enriching lives around the world with the safest and most responsible ways to transport people*", and Siemens, "*We are constantly renewing our portfolio to provide answers to the most vital challenges society, allowing us to create sustainable value*", reinforce this relationship of innovation and social change.

This was the most common feature found in the companies' proposals. It is related to a perspective of technological development, where the innovation of EVs, AVs, and eVTOLs becomes a purpose of the firms. Corroborating this perspective, the analysis based on the model of Kastrinos and Weber (2020) presents innovation as the main focus of organizations. The model presents innovation as a tool to take advantage of the forces and mechanisms of change, where it is possible to verify that the innovation ecosystem is the great driver of the researched firms' strategy. In this way, the SDGs work as an incentive to transform the current hegemonic ecosystem (focused on the ICE market) into an ecosystem more focused on sustainable development. It is possible to infer that the change in the technological paradigm is visible both in the organizations' strategies and in the technologies of the mobility sector. This corroborates with the current literature, where this change to sustainable businesses reflects corporate values and culture (Rosli et al., 2019). The results of EVs, AVs, and eVTOLs also corroborate with the literature as potential disruptive innovation changing the value network (Adner & Kapoor, 2016; Brandenburger & Nalebuff, 1996; Petzold et al., 2019), restructuring of value chains (Cozzolino et al., 2018; Yaghmaie & Vanhaverbeke, 2019), and with an ecosystem with develops and grows around disruption (Palmié et al., 2019).

4.3. Analysis of Technological Concentration by Countries

Technological concentration concerns the number of firms analyzed in each country (Figure 4), where it is possible to see that the USA (30%) and Japan (20%) predominate, with half of the firms related to the development of mobility technologies. In addition to the predominance of the USA and Japan, technological concentration is evident in a few geographic regions.

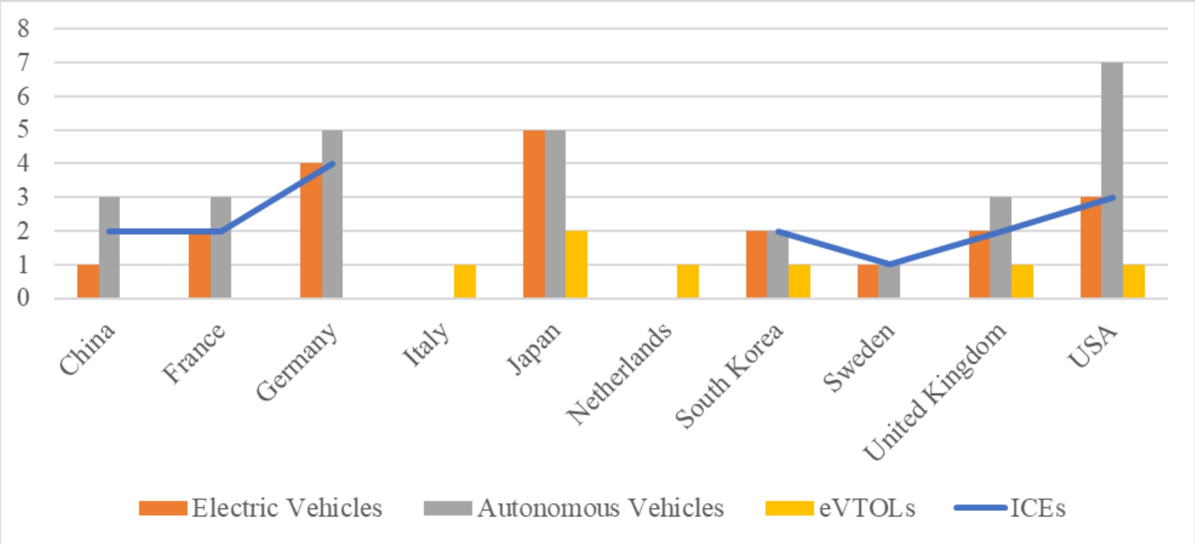
Figure 4 – Technological Concentration by Countries.



Source: Research data.

Figure 5 represents the technologies developed by the firms studied in each country. Note, therefore, that there is no emphasis on technologies by continents but by countries. Firms in Italy, Japan, and the Netherlands do not have information on the development of combustion technologies, focusing on the technologies of EVs, AVs, and eVTOLs. The information found in firms in China is the only one where ICEs outperform EVs. In other countries, firms' information about EV technology is similar. Information from firms about eVTOLs technologies is still modest in most countries, while AV technologies are equal to or superior to all others.

Figure 5 – Technologies by Country.



Source: Research data.

Overall, ICE technologies accounted for 27.06% of missions, while EVs were 23.53%, AVs were 37.65%, and eVTOLs 11.76%. In this sense, it is important to verify that, considering that these technologies use electric powertrains, the information on the electrification of vehicles is already responsible for approximately 72.94% of the firms' missions, which surpasses the information on ICE technology, which is predominant in the world market (Yan, Tseng & Lu, 2018). With this result, it is possible to infer that a change in technological perspective is taking place (Attias, 2016; Meyer et al., 2017; Wadud, 2017), and that the change in transportation mobility platforms is receiving increasing importance.

The analysis of technological concentration by Countries shows the high concentration of technology development in a small group of countries, with the USA and Japan concentrating 50% of the companies. This research's technological development paradigm provided an idea for technological concentration in the northern hemisphere (Horner, 2019; Huang et al., 2012). We can explain the technological concentration by a sustained accumulation of scientific and technological infrastructure, more mature markets, and a lower risk of investment in technologies. The formation of technological conglomerates may denote specific incentives from the governments of these countries for developing more sustainable technologies and with greater concern for the future of transportation mobility. These practices would be encouraged by actions aimed at achieving the SDGs. It can also indicate similarity in activities, difficulties, and incentives received in this sector, in addition to the possible formation of strategic alliances, which is facilitated by geographic proximity.

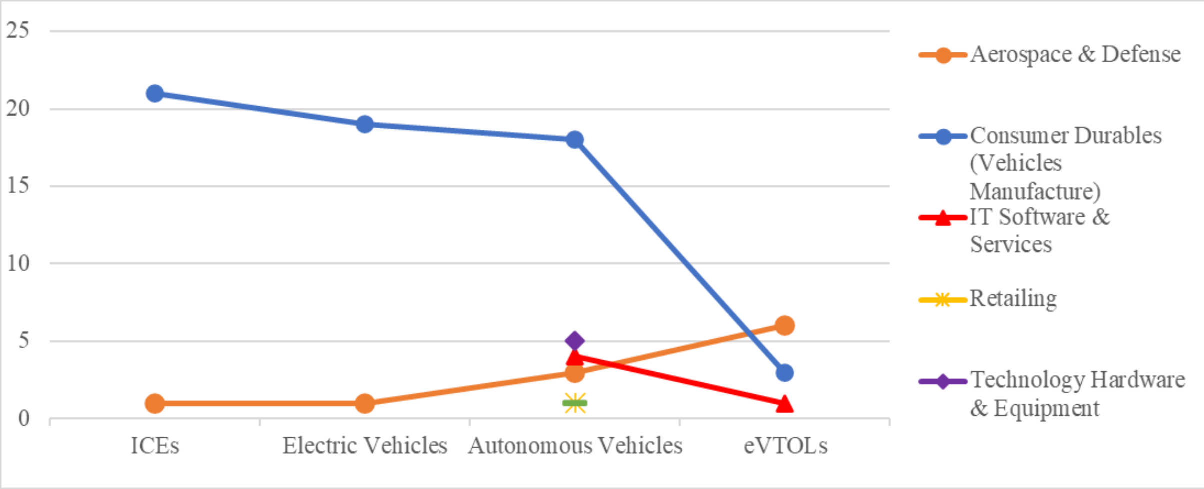
These results are according to the literature where the formation of innovation networks and ecosystems is a common way to mitigate costs and risks (Adner & Kapoor, 2010; Leten et al., 2013; Yaghmaie & Vanhaverbeke, 2019), to collaborate (Granstrand & Holgersson, 2020; Moore, 1993), and co-evolution for continuous innovation (Hou & Shi, 2020; Silva & Grützmann, 2022). According to the literature, within a disruption, actors must unite the new ecosystem in search of complementary resources from those responsible for the ecosystem (Kumaraswamy et al., 2018). As exemplified by the Governance category for the union of organizations to change the technological standard and the mission of Hyundai Motors that seeks collaboration, synergy and cooperation between market partners, the joint development of technology is an important tool for developing the entire industry.

It is important to verify that, considering information on the electrification technology of vehicles is already responsible for approximately 72.94% of the firms' missions, which surpasses the information on ICE technology, which is predominant in the world market. This is a change in the perspective of the current literature, where only a small percentage of the world's fleet from vehicles from alternative sources (Yan et al., 2018). In agreement, according to the literature, our results show that is a change in technological perspective is taking place (Attias, 2016; Meyer et al., 2017; Wadud, 2017), and that the change in transportation mobility platforms is receiving increasing importance. The indication of technological concentration by countries can be an important way of presenting the transformation of the existing pattern being changed in some markets.

4.4. Technological Transition Analysis

Figure 6 shows the transition from ICE technologies to EVs, AVs, and eVTOLs. It suggests that firms focused on Consumer Durables, basically automobile manufacturers, dominate the production of ICEs and EVs technologies. The Aerospace & Defense firm on the list of ICEs, and EVs technologies is Rolls-Royce, and it produces both types of technology. With the arrival of AV technology, the dispersion of areas becomes greater, where it needs different technologies to develop vehicle automation. Firms such as IT Software & Services, Retailing, Technology Hardware & Equipment, and Telecommunications Services are starting to get involved in the transportation mobility market, which configures changes and advances in technologies. On eVTOLs technology, the Aerospace & Defense firms have surpassed Consumer Durables (Automobiles) in their focus on technological development.

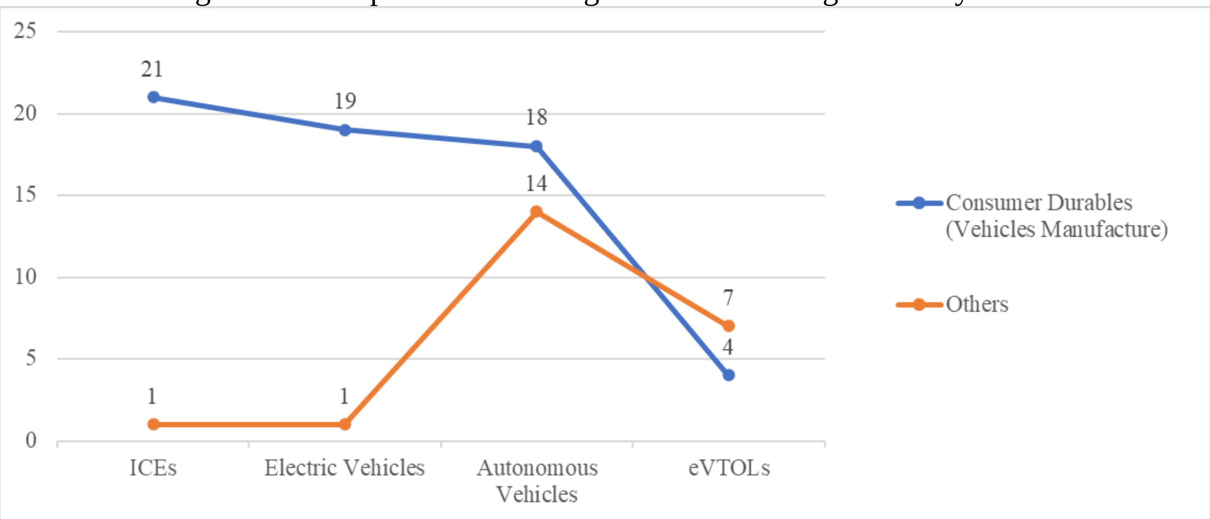
Figure 6 – Technological Development Areas.



Source: Research data.

Finally, Figure 7 compares Consumer Durables (Automobiles) firms with other firms. It is possible to verify that the technological standard is maintained in the technologies of ICEs and EVs. However, in AV technologies, 43.75% of firms are outside the car manufacturing sector, while for eVTOLs, it is 63.64%. It is important to emphasize that eVTOLs technology is aimed at transport by air as an alternative to land transport, so it is feasible that firms in the aerospace sector are involved in this development.

Figure 7 – Comparative of Change in the Technological Ecosystem.



Source: Research data.

It is possible to see that, with the development of the four technological perspectives (ICEs, EVs, AVs, and eVTOLs), the driving force of transportation mobility is moving towards the electrification and automation of vehicles. As exemplified by Daimler: "*Implementing driving* *electrical in all divisions as a priority. Promote automated and autonomous driving and mobility services with a focus on customer benefit and profitability*". Electric, autonomous and air transport is also a reality, which was observed at Uber: "*we are working to bring the future closer with self-steering technology and urban air transport*".

In the Technological Transition from ICE technologies to EVs, AVs, and eVTOLs, the driving force of transportation mobility is moving toward the electrification of vehicles and vehicle automation. This movement of the companies to a new and growing technology is according to the literature on disruptions (Berglund & Sandström, 2017; Christensen et al., 2018; Cozzolino et al., 2018) and disruptive ecosystems (Dedehayir et al., 2017; Palmié et al., 2019; Silva et al., 2022). It is noteworthy that the ecosystem is being created to leverage the new technological standard. The change in the technological paradigm shown in Figures 6 and 7 highlights the entry of firms from outside the automotive industry in developing new technologies in the transportation mobility market. These new entrants are according to the disruption literature (Bohnsack et al., 2021; Christensen et al., 2018; Sood & Tellis, 2011). Our results show that vehicle manufacturing, aircraft, information technology, telecommunications, hardware and software technologies, among others, are coming together to develop the new disruptive technological standard in which the ecosystem will flourish. According to the literature, the disruptive pattern relies on the existing ecosystem to develop the disruption itself (Beltagui et al., 2020; Palmié et al., 2019).

With our results show a technological concentration of firms that develop new mobility technologies in more technologically developed countries and the change of value proposition of the firm to an electrification scenario of the vehicles, agreeing with the current literature (Constantinescu & Frone, 2014; Jordão, 2022; Njoroge et al., 2019; Ordonez-Ponce et al., 2021). The results show that the SDGs are a tool that drives firms' development of more sustainable innovations. It is possible to understand that a change in the strategic and technological paradigm is taking place. According to the literature, an ecosystem grows around a disruption (Palmié et al., 2019), which develops a new dynamic of capturing and delivering value and restructuring the entire ecosystem (Adner & Kapoor, 2016; Yaghmaie & Vanhaverbeke, 2019). In this way, the current mobility ecosystem focused on ICE technology is changing to a new technological standard centered on electrification, automation and, possibly, exploration of the transportation aerial dimension. This new perspective of power sources and the exploration of urban space are potentially disruptive innovations in the constitution of a new mobility ecosystem.

5. Contributions

5.1. Theoretical Contributions

As a theoretical contribution, this research brings advances in the literature on disruptions (Berglund & Sandström, 2017; Christensen et al., 2018; Cozzolino et al., 2018) and disruptive ecosystems (Dedehayir et al., 2017; Palmié et al., 2019; Silva et al., 2022), where the new technologies of EVs, AVs, and eVTOLs begin to emerge among the different technology industries and the technological clusters function as a basis for the ecosystem development of innovations. This contribution reinforces the impact of disruptions on the ecosystem and, according to the research results, shows the change in a value proposition presented by companies based on the disruption. As pointed out in the first gap of this research, this transition presents a transition from the value proposition of transportation mobility in search of more sustainable technologies, possibly autonomous and open to airspace. This disruptive impact also opens space for research related to the growth of the disruptive ecosystem of new technologies.

This study also contributes to implementing SDGs by private organizations (Ali et al., 2018; Hák et al., 2016; Kastrinos & Weber, 2020; Leal Filho et al., 2017). It also contributes to discussions on transportation mobility, reinforcing the idea of change in the sector based on aspects of sustainable development (Kivimaa & Kern, 2016; Nidumolu et al., 2009; Williams, 2014). This also related to the second gap of this study about the companies' engagement with SDGs strategic opportunities. Thus, this research presents the tendency in the transportation mobility industry for companies to seek cleaner technologies and, therefore, greater investment in the areas of "industry, innovation and infrastructure" of the SDGs. In this criterion, innovation is a force to drive more sustainable change. In addition, there is a discussion in the literature regarding the opportunity for companies to integrate sustainability into key business strategies and invest in more sustainable practices to take advantage of the wave of change in the disruptive ecosystem.

This study also contributes to understanding the change of the current ecosystem paradigm to a more sustainable disruptive ecosystem pattern (Dedehayir et al., 2017; Kumaraswamy et al., 2018; Palmié et al., 2019). In this case, the disruption caused by new technologies is integrated with the organizations' missions, visions and objectives, creating a new ecosystem. These signs of change in the transportation mobility ecosystem are close to innovation and infrastructure relationships but do not necessarily point to a specific perspective of the SDG initiative. It adds to the literature that the SDGs are not objective of change but the innovation of the technological standard and, consecutively, some sustainable objectives.

5.2. Practical Contributions

As a managerial contribution, it allows managers of other public and private entities to reflect on sustainability issues and the adequacy of the SDGs for disruptive changes in ecosystems. Ecosystem change is starting with several leading technologies and market players. Accompanying this change is an opportunity for managers and companies to position themselves in the new ecosystem that is born based on disruptions and position themselves based on the sustainable demands of the market. The SDGs are important guidelines for the sustainable development of the ecosystem and for entrants to progress with sustainable thinking. These sustainable innovations that can disrupt the ecosystem are an opportunity for organizations to add sustainability as part of business strategies, developing technologies, and exploring markets.

6. Final Remarks

The impact of potentially disruptive and more sustainable technologies is bringing a shift in today's mobility ecosystem. This study analyzes how potentially disruptive innovations can change the current technological transportation mobility ecosystem and focus on a sustainable perspective. For this, we used the content analysis of the mission, vision, and values of firms that develop transportation mobility technologies in the 1,000 largest firms on the Forbes list (2020). The sample focused on projects related only to ICEs, EVs, AVs, and eVTOLs.

To focus on analyzing the current change in the transportation mobility technological ecosystem, it was possible to report that "industry, innovation and infrastructure", "sustainable cities and communities", "dignified work and economic growth", and "sustainable production and consumption" are the most apparent objectives within the strategies of the organizations. There is a greater concern about organizational strategies with the SDGs related to developing a new, more sustainable market, intending to continue economic growth (Hák et al., 2016). Therefore, these goals converge to developing new transportation mobility technologies, especially sustainable ones. Furthermore, they allow us to infer that the transportation mobility ecosystem has transcended the current paradigm (ICEs) in search of a more sustainable ecosystem.

In this sense of new market development, innovation can be the main strategic factor for organizations (Kastrinos & Weber, 2020). Thus, the results also show the impact of potentially disruptive technologies, such as EVs, AVs, and eVTOLs. From the perspective of more sustainable ecosystem change, the SDGs are a form of incentive to change the current technological paradigm (ICEs) to a more focused on sustainable development (EVs, AVs, eVTOLs) (ICSU, 2020; Kastrinos & Weber, 2020; Leal Filho et al., 2017). The technological concentration in northern countries, especially the USA and Japan, may indicate the formation of technological and strategic networks and ecosystems (Leten et al., 2013), collaboration, complementarity, and competition relationships (Granstrand & Holgersson, 2020), and even government incentives for the development of more sustainable technologies aimed at achieving the SDGs and with greater concern for the future of transportation mobility.

As shown in Figures 6 and 7, the insertion of firms in the aerospace, software, hardware, and telecommunications sectors shows the change that is taking place in the transportation mobility sector. As new technologies develop, new sectors are needed to consolidate the ecosystem. Thus, it is possible to verify a change in the technological strategy of organizations (Attias, 2016; Meyer et al., 2017; Wadud, 2017). The transportation mobility ecosystem begins to change to potentially disruptive (Palmié et al., 2019) and more sustainable technologies, restructuring the value chains of the innovation and business ecosystem (Adner & Kapoor, 2016; Yaghmaie & Vanhaverbeke, 2019). From this perspective, the change in the current technological paradigm, ICE technology, makes room for the new strategic and technological paradigm aimed at electric, autonomous and aerial mobility technologies.

As for the study limitations, the sample used is due to the lack of a database on mobility that addresses information from firms in this sector. This study is also limited by being a recent research topic and dependent on the availability of data by organizations. It is important to analyze the future directions that organizations will take. Another limitation regarding the data is that the firms' missions, visions, and objectives may have been written without a real commitment to the SDGs and to the market, where further studies would be needed to confront the strategic proposals and the real practices of organizations' market. The analysis of three researchers can also be considered a weakness, where new technical perspectives can contribute to the development of the study area. As an agenda for future research, there is a need to carry out this investigation with other types of organizations, such as startups, the renewable energy sector and other businesses that need to be sustainable. Furthermore, the use of other bases also becomes interesting. New research is also important to design the change in the value proposition of inserting new technologies into the existing transportation mobility ecosystem. A longitudinal case study is suggested to explore the changing value proposition of the transportation mobility market. Finally, seeking new data sources, new analysis tools and confronting organizations' proposals and market practices are demands for future deepening.

ANNEX I - List of Related Companies and Technologies.

Firms	Area	Fundation	Country	ICE	EV	AV	eVTOL
Toyota Motor	Consumer Durables	1937	Japan	X	X	X	
Alphabet/Google	IT Software & Services	2015	USA			X	
Volkswagen	Consumer Durables	1937	Germany	X	X	X	
Intel	Technology Hardware & Equipment	1968	USA			X	
Tencent	IT Software & Services	1998	China			X	
IBM	IT Software & Services	1911	USA			X	
General Electric	Technology Hardware & Equipment	1892	USA			X	
Siemens	Technology Hardware & Equipment	1847	Germany			X	
BMW	Consumer Durables	1916	Germany	X	X	X	
Honda	Consumer Durables	1948	Japan	X	X	X	X
Raytheon Technologies	Aerospace & Defense	1922	USA	X	X	X	X
General Motors	Consumer Durables	1908	USA	X	X	X	
Mitsubishi	Consumer Durables	1950	Japan	X	X	X	
Dell Technologies	Technology Hardware & Equipment	1984	USA			X	
Honeywell International	Aerospace & Defense	1885	USA			X	X
Orange	Telecommunications Services	1991	France			X	
Hyundai Motor	Consumer Durables	1967	South Korea	X	X	X	X
Hitachi	Technology Hardware & Equipment	1910	Japan			X	
Fiat Chrysler Automobiles	Consumer Durables	2014	United Kingdom	X	X	X	
Volvo Group	Consumer Durables	1927	Sweden	X	X	X	
JD.com	Retailing	1998	China			X	
Peugeot (Grupo PSA)	Consumer Durables	1896	France	X	X	X	
Daimler	Consumer Durables	1886	Germany	X	X	X	
BAE Systems	Aerospace & Defense	1979	United Kingdom			X	
Boeing	Aerospace & Defense	1916	USA				X
AIRBUS	Aerospace & Defense	1998	Netherlands				X
KIA Motors	Consumer Durables	1944	South Korea	X	X	X	
Subaru	Consumer Durables	1953	Japan	X			X
Suzuki Motor	Consumer Durables	1920	Japan	X			
Ford Motor	Consumer Durables	1903	USA	X	X	X	
Nissan Motor	Consumer Durables	1933	Japan	X	X	X	
Tesla	Consumer Durables	2003	USA		X	X	
Porsche Automobil Holding	Consumer Durables	1930	Germany	X	X	X	
Dongfeng Motor Group	Consumer Durables	2001	China	X	X		
Uber	IT Software & Services	2009	USA			X	X

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ARTICLE 3 - THE EFFECTS OF TECHNOLOGICAL LEAPFROGGING IN TRANSPORTATION TECHNOLOGIES IN BRICS AND G7 COUNTRIES

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Motivation is the catalyzing ingredient for every successful innovation.
The same is true for learning.
(Clayton M. Christensen).

THE EFFECTS OF TECHNOLOGICAL LEAPFROGGING IN TRANSPORTATION TECHNOLOGIES IN BRICS AND G7 COUNTRIES

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Abstract:
Purpose: To analyze the technological, economic, and environmental impacts of the potentially disruptive innovations in the transportation mobility market
Design/Methodology/Approach: This article uses data on Energy Consumption, Economic Development, and Reduction of Greenhouse Gas Emissions to highlight the advantages of Electric Vehicles (EVs), Autonomous Vehicles (AVs), and Electric Vertical Take-off and Landing Technologies (eVTOLs).
Findings: The results suggest positive implications for technological leapfrogging of EV, AV, and EVTOLs, such as gains in energy consumption, infrastructure improvement, greenhouse gas emissions reduction, economic growth, and the opportunity for new disruptive technologies to revolutionize the entire transportation ecosystem.
Originality: The paper contributes to the technological, economic, and sustainable leapfrog research focusing on EVs, AVs, and eVTOLs. Disruptive technologies' impacts on the transportation mobility market in developed and developing countries and opportunities for technological leapfrogging are explored and discussed.
Research Limitations/Implications: This study uses data sets from World Bank and other sources, assumes ceteris paribus to compare G7 and BRICS, and therefore is limited by these choices. Disruptive innovation theory could benefit from exploring technological, economic, and environmental leapfrog possibilities. The results present market scenarios for EVs, AVs, and eVTOLs technologies, considering a total replacement of Internal Combustion Vehicles (ICE).
Practical Implications: This study emphasises potentially disruptive technologies' technological, economic, and sustainable benefits. Organizations can delve into results to investigate coming markets and seek advantageous positions. Social gains from leapfrogging could motivate government bodies to finance research focusing on EVs, AVs, and eVTOLs.
Keywords: Technological Innovation, Disruptive Innovation, eVTOLs, Technological Leapfrogging, Economic Growth, Transportation Technology, Sustainability.
Paper Type: Research paper

1. Introduction

Developed and developing countries must seek technologies that can change social (Marletto, 2019), environmental (Skeete, 2018), economic (Jin *et al.*, 2018), and sustainable patterns (Afrifa *et al.*, 2020; Kamoun *et al.*, 2020), since technology plays a central role in driving productivity and economic development (Schniederjans, 2017). However, strategy, technology development, and innovation research mainly focus on industrialized nations (Peng, 2014).

Transportation is essential for the economy (Durst and Leyer, 2022; Kyriacou *et al.*, 2018) and a facilitator for sustainable growth (Afrifa *et al.*, 2020; Kyriacou *et al.*, 2018; Marletto, 2019; Mello *et al.*, 2021; Ofinade and Alola, 2022). Developing countries can benefit from the early adoption of innovations (Goldemberg, 2019), focusing on new transport technologies (Seum *et al.*, 2020), such as new power supplies, autonomous driving, and the forthcoming air transport (Uber Elevate, 2016). Emerging countries are scenarios where researchers can study technological innovations (Amankwah-Amoah *et al.*, 2021; Kapidani and Luci, 2019), which allow faster updating and development, leading to technological leapfrogging or catching up with developed countries (Afrifa *et al.*, 2020; Jin *et al.*, 2018).

Disruptive innovations start with a small market share and evolve to change well-established markets, displacing leading companies (Christensen *et al.*, 2018). Electrical Vehicles (EVs) are available in developed countries and a few developing countries, while Autonomous Vehicles (AVs) and electric Vertical Take-Off and Landing (eVTOLs) are in the testing phase, promising a competitive advantage in the next decade (Gartner, 2018). Since smart city studies highlight new mobility, those potentially disruptive technologies deserve attention as an opportunity to revolutionize the transportation ecosystem (Dedehayir *et al.*, 2018; Palmié *et al.*, 2019; Silva and Grützmann, 2022; Stone *et al.*, 2019).

Whether disruption in transportation systems is imminent, society needs to investigate future sustainable options (Sprei, 2018). Studies indicate the possibility of transitioning to zero-carbon and renewable energy systems' benefits (Diesendorf and Elliston, 2018), despite the questions about existing energy systems' capacity to support EVTOLs (Garrow *et al.*, 2021). Therefore, changes in mobility systems should consider both positive and negative externalities, ranging from climate change and deforestation to accidents and congestion.

This study addresses those gaps by exploring potentially disruptive innovations that can change the market's value proposition (Christensen *et al.*, 2001, 2018; Yaghmaie and Vanhaverbeke, 2019). The article compares the Group of Seven (G7 – Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) and the BRICS (Brazil, Russian Federation, India, China, and South Africa) since the gross domestic product (GDP), information and communications technology (ICT) development, and CO2 emissions of the latter are considerable (Haseeb *et al.*, 2019).

Incumbents tend to commit to established technologies due to substitution costs, while innovation technologies may be more attractive to low-wage countries (Heiden, 2016). The ideal timing for leapfrogging is unknown, and diverse research methods should be used to explore this phenomenon (Zhang *et al.*, 2021). Given the significance of the G7 and BRICS and transportation mobility's relevance to society, this study questions: what are the impacts of replacing the current ICE fleet with EVs, AVs, and eVTOLs in the transportation mobility market?

The primary purpose was to analyze the technological, economic, and environmental impacts of the potentially disruptive innovations in the transportation mobility market. The results show latent benefits of technological leapfrogging in the transport ecosystem for both groups. This study adds to the academic literature on disruptive innovations by emphasizing the potential gains of upcoming transportation mobility technologies and juxtaposing emerging and developed countries' technological landscapes. This paper incentives new comparative studies on potentially disruptive technologies since it recognizes leapfrogging's benefits in transportation mobility technologies.

Regarding economic contributions, the paper highlights G7 and BRICS countries with greater benefits in energy savings, GDP increase, and CO2 emissions reductions. From a managerial perspective, organizations can use the provided scenarios to understand incipient markets and pursue advantages. Based on the paper's estimations, firms can search for collaboration or partnerships in the most promising markets. The results would be helpful both to incumbents to take action to protect their markets and new entrants to open up opportunities.

Alongside the aforementioned contributions, in the social dimension, the article endorses former studies showing the benefits of replacing fossil fuel transportation with sustainable technologies such as EVs, AVs, and eVTOLs. It also presents future scenarios for the arrival of these new technologies to accelerate the technological, economic, and sustainable transformation of emerging countries. Ultimately, it subsidizes policymakers and government bodies to foster initiatives or projects to expedite new transportation technologies aiming at CO2 emission reduction and sustainable development.

2. Literature Review

2.1. Technological Innovation in the Transportation Market

Currently, the world has about 1.3 billion vehicles (OICA, 2015), which is approximately one motor vehicle per seven people, with the vast majority of these vehicles still powered by internal combustion engines (ICE) and less than 1% using alternative energy sources (Yan *et al.*, 2018). Despite the complexity of transitioning to a new mobility system (Mello *et al.*, 2021), disruptive technologies such as EVs, AVs, and eVTOLs can trigger a significant and transformative change in the automotive industry (Skeete, 2018).

Electrification technology has brought different perspectives to transportation modalities. EVs can lower transportation costs and may decrease global pollutant emissions, but they require new infrastructure adaptations (Alghoul *et al.*, 2018). AVs' disruptive innovations (Skeete, 2018) have introduced new transport possibilities since they can be safer (Fagnant and Kockelman, 2015) and sustainable (Wadud and Anable, 2016), opening up possibilities for new business models, vehicle ownership, and sharing (Merfeld *et al.*, 2019).

EVTOLs combine vertical propulsion with long-life electric batteries and flight control automation, communication, and navigation mechanisms, which may disrupt the transportation mobility market. This concept provides safe, sustainable, and accessible air transport for passenger mobility and cargo delivery (Reich *et al.*, 2021). EVTOLs can move transportation from the land to the air (Cohen *et al.*, 2021; Uber Elevate, 2016). Companies are developing eVTOLs technology to make it a reality (Cohen *et al.*, 2021; EmbraerX, 2020; Uber Elevate, 2016).

EVs are being marketed in more developed countries while emerging economies are taking initial steps toward this technology (Mersky *et al.*, 2016). AVs can transform existing transportation structures, such as substantially decreasing the total vehicle fleet (Bösch *et al.*, 2016) and reducing congestion (Fagnant and Kockelman, 2015). AV technologies are in the testing phase and close to the market (Wadud and Anable, 2016). Depending on the AVs and eVTOLs business models, both can "compete" for pedestrians over medium-distance ranges, complementary to short, medium, and long distances (Uber Elevate, 2016). EVTOLs are in an early stage but tend to grow while the EVs and AVs materialise and become the primary transportation air mobility solution in the near future (EmbraerX, 2020; Uber Elevate, 2016). The new technologies can shake and grow the market and its market share. Even though ICEs are still the current technology, as EVs, AVs, and eVTOLs are developed, they will have the opportunity to grow in the market and guarantee their space in transportation mobility.

2.2. Technological Innovation and Economic Development

Emerging countries invest less in innovative technologies and are less competitive in research and development funding (Kapidani and Luci, 2019). In this sense, technology and innovation are a source of transformation in these countries (Amankwah-Amoah *et al.*, 2021), which can create effective strategies for incorporating innovative technologies into emerging markets as "learning laboratories" to develop market capacity, resources, and power (Amankwah-Amoah and Debrah, 2014).

By investing in technology, less developed countries can positively impact technological development and economic growth (Giri *et al.*, 2021) and technologically leapfrog (Mello *et al.*, 2021). By following this path, these countries avoid building specific expensive infrastructure and can leapfrog directly into newer technologies to promote further economic development (Amankwah-Amoah, 2015). Thus, when a disruptive innovation changes technology standards, it can create significant growth in the sector (Christensen *et al.*, 2001; Silva and Grützmann, 2022), enabling emerging countries to reach or even surpass developed countries and making them competitive in the global stage (Wang and Zheng, 2022).

Technology innovation is a source of growth and is crucial for emerging economies to continue to grow (Faghih *et al.*, 2018). Even with the challenges to growth and economic development in emerging economies, technological leapfrogging is occurring rapidly (Amankwah-Amoah, 2015). The innovations of EVs, AVs, and eVTOLs can disrupt the transportation mobility market and represent an opportunity for technological leapfrogging. Depending on the different technological models countries adopt, there may be different growth and development rates.

2.3. Technological Innovation and Sustainable Results

Technological innovation can be seen as a means of achieving economic growth and a key factor for sustainable development (Amankwah-Amoah *et al.*, 2021; Mello *et al.*, 2021). Developing and developed nations will need a greener economy to reduce CO2 emissions worldwide. In this sense, technological innovation can positively affect sustainable growth (Kamoun *et al.*, 2020). Thus, it can be argued that the relationship between technological progress and economic growth is positive. Ecodevelopment has emerged as an alternative to the classical development idea, assuming a role in consolidating development and the environment (Mello *et al.*, 2021).

Climate change is a significant challenge for economies, especially developing ones (Renwick, 2017). However, increasing public investment in transport infrastructure will not necessarily lead to efficient results (Kyriacou *et al.*, 2018; Mello *et al.*, 2021). In the case of the BRICS economies, their dependence on fossil fuels is a problem, and it underpins much of their global carbon dioxide (CO2) emissions (Gu *et al.*, 2018). The BRICS investments in technological innovation may positively change their economic development with impacts on CO2 emissions (Santana, Maniano, *et al.*, 2015). When a technological innovation impact occurs in one of the BRICS countries, it can also be transferred to other countries (Cowan *et al.*, 2014), which expands potential technological diffusion in these markets (Kassens-Noor *et al.*, 2021; Silva *et al.*, 2022).

It is accepted that financial development, energy consumption, and CO2 emissions are positively related. In this sense, financial development leads to economic development driven by energy consumption, where energy is considered a prerequisite for sustainable economic development (Raghutla and Chittedi, 2021). It is also worth noting that technological innovation plays a central and driving role in productivity and economic development (Amankwah-Amoah *et al.*, 2021), and most emerging countries do not have technologies to deal with CO2 emission levels (Amiolemen *et al.*, 2012). While the demand for transportation mobility increases substantially as economic development advances in countries worldwide (Seum *et al.*, 2020), the search for renewable and sustainable energy sources becomes essential to growth. Thus, introducing new technological innovations through a change in transportation mobility perspectives can impact energy consumption and CO2 emissions. Considering that the BRICS are also representative, their impact is increasingly relevant for international policies and economies (Song *et al.*, 2013).

It is essential that the innovative strategy influences long-term economic sustainability (Njoroge *et al.*, 2019). In the BRICS, fossil fuels are expected to continue as an energy source in the coming years (Gu *et al.*, 2018). Transportation modes still rely heavily on fossil fuels, which account for a quarter of world production of greenhouse gas emissions. Adopting innovative technologies may reduce emissions and provide substantial economic gains (Yan *et al.*, 2018). Therefore, the possible impacts of innovative technologies like EVs, AVs, and eVTOLs are critical for developing future transportation markets.

3. Methods

This exploratory study compared data between the G7 major world powers and the developing BRICS on their most used transportation types (Santana, Aparecida, *et al.*, 2015; Santana, Maniano, *et al.*, 2015). This work performed arithmetic calculations on energy consumption, economic development, and greenhouse gas emissions reduction data. Previous studies used regulations, reports, interviews, and statistics (Heiden, 2016) or secondary data for calculations or statistics tests to investigate leapfrogging or transportation issues (Afawubo and Noglo, 2022; James, 2014; Niebel, 2018; Sovacool *et al.*, 2021).

This exploratory work used nineteen open data sources for prospecting future innovation technology outcomes when completely replacing the current fossil fuel-based technology standard with EVs, AVs, and eVTOLs. The latest available sources were preferred and are shown in Table 1. Several pages with different accesses were used to collect data between 2020 and 2021. Previous studies relied on databases from Energy Consumption (Arokiaraj *et al.*, 2020; Greene *et al.*, 2017; Khan *et al.*, 2022; Le *et al.*, 2021; Wali *et al.*, 2018), Economic Development (González-Blanco *et al.*, 2019; Kergroach *et al.*, 2018; Pitelis *et al.*, 2019; Rigo, 2021; Wang and Wei, 2020), and

Reduction of Greenhouse Gas Emissions (Arokiaraj *et al.*, 2020; González-Blanco *et al.*, 2019; Greene *et al.*, 2017; Khan *et al.*, 2022; Le *et al.*, 2021; Rigo, 2021; Wali *et al.*, 2018).

Table 1 – Data for Analysis

Discussion Category	Acronym	Data Analysis	Source
Energy Consumption	MR	Motorization Rate by Country	OICA (2015) (http://www.oica.net/category/vehicles-in-use/)
	GC	Gasoline Cost by Country (liter, U.S. Dollar)	Global Petrol Prices (2021) (https://www.globalpetrolprices.com/)
	ICEC	Consumption of the best selling Combustion Vehicle in the world in 2020	Auto Express (2020) (https://www.autoexpress.co.uk/news/33872/worlds-best-selling-cars)
	KM	Annual KM traveled by Country (KM Daily * 365)	Nation Master (2014) (https://www.nationmaster.com/country-info/stats/Transport/Commute/Distance)
	EC	Electricity Cost by Country (kWh, U.S. Dollar)	Global Petrol Prices (2020) (https://www.globalpetrolprices.com/)
	EV	Consumption of most sold EV in the world	Fuel Economy (2021) (https://www.fueleconomy.gov); Statista (2021) (https://www.statista.com/statistics/960121/sales-of-all-electric-vehicles-worldwide-by-model/#:~:text=The Tesla Model 3 was,Tesla's sales volume in 2020)
	AV	AV Consumption closest to the Market	Cars US News (2020) (https://cars.usnews.com/cars-trucks/cars-that-are-almost-self-driving); Fuel Economy (2021) (https://www.fueleconomy.gov)
	eVTOL	Estimated eVTOL Consumption	Uber Elevate (2016)
	ICEC Cost		
	EVs/AVs/eVTOLs Cost		
	Gain from EV/AV/eVTOL		
Economical Development	TII	Transport Infrastructure Investment	OECD (2017) (https://data.oecd.org/transport/infrastructure-investment.htm)
	ICEC	Consumption of the best selling Combustion Vehicle in the world in 2020	Auto Express (2020)
	EV	Consumption of most sold EV in the world	Fuel Economy (2021); Statista (2021)
	AV	AV Consumption closest to the Market	Cars US News (2020); Fuel Economy (2021)
	eVTOL	Estimated eVTOL Consumption	Uber Elevate (2016)
	GDP	GDP per capita (current US$)	The World Bank (2021) (https://data.worldbank.org/indicator/)
	MR	Motorization Rate by Country	OICA (2015
	PC	Population by Country	World o Meters (2021) (https://www.worldometers.info/world-population/population-by-country/)
	Income Increase in Transport Infrastructure (% Increase TII)		
	Earned by EVs/AVs/eVTOLs		
	EVs/AVs/eVTOLs Increase per capita		
Greenhouse Gases Emission Reduction	CO2L	CO2 emissions from liquid fuel consumption (kt)	The World Bank (2021)
	CO2T	CO2 emissions from transport (% of total fuel combustion)	The World Bank (2021)
	MR	Motorization Rate by Country	OICA (2015)
	KM	Annual KM traveled by Country (KM Daily * 365)	Nation Master (2014)
	EV	Consumption of most sold EV in the world	Fuel Economy (2021); Statista (2021)

AV	AV Consumption closest to the Market	Cars US News (2020); Fuel Economy (2021)
eVTOL	Estimated eVTOL Consumption	Uber Elevate (2016)
CO2EC	Total CO2 Emissions (kt) per Coutry	The World Bank (2021)
CO2E	CO2 from electricity generation (g/kWh)	Compare your Country (2014) (http://www.compareyourcountry.org/climate-policies?cr=oecd&lg=en&page=2)
Total CO2 Emissions from Transport (CO2T)		
Total CO2 Generated from Electricity Production (TCO2E)		
CO2 Generated in the Production of Energy (CO2PE)		
% EVs/AVs/eVTOLs CO2 Transport Reduction		
% EVs/AVs/eVTOLs CO2 ODS Reduction		

Source: Research Data.

The formulas and descriptions for the calculations are shown next. The first category was **Energy Consumption**. The formula to calculate the ICECs Energy Consumption (ICEC Cost) uses the Motorization Rate by Country (MR), which is based on data from the fleet by country (OICA, 2015) and divided by the Gasoline Cost by Country (GC) (Global Petrol Prices, 2021). The result was then multiplied by the consumption of the bestselling vehicle in the world in 2020 (ICEC) (Auto Express, 2020) by the annual km transport by country (KM) (Nation Master, 2014). ICEC Cost was obtained using the following formula (Figure 1).

$$ICEC\ Cost\ = \left(\frac{MR}{GC}\right) \times ICEC \times KM$$

The EVs/AVs/eVTOLs Cost represents replacing gas for electricity. The gasoline cost was replaced by the Electricity Cost by Country (EC) (Global Petrol Prices, 2020) and multiplied by the Motorization Rate by Country (MR) (OICA, 2015), the annual km transport by country (KM) (Nation Master, 2014), and one of the new technology patterns (EV or AV or eVTOL). The consumption of the most sold EV in the world (Fuel Economy, 2021; Statista, 2021), the consumption of the closest AV to the market (Cars US News, 2020; Fuel Economy, 2021), and the estimated eVTOL consumption (Uber Elevate, 2016) were used. With electricity cost by country and EVs/AVs/eVTOLs consumption, it was possible to calculate each transport modality with the formula below.

$$(EV/AV/eVTOL)\ Cost\ = MR \times KM \times EC \times (EV/AV/eVTOL)$$

The Gain from EV/AV/eVTOL uses the ICE Cost and EV/AV/eVTOL Cost and is expressed by the following equation.

$$Gain\ from\ (EV/AV/eVTOL) = ICEC\ Cost - (EV/AV/eVTOL)\ Cost$$

The following calculations are related to **Economic Development**. The Income Increase in Transport Infrastructure (% Increase TII), expressed below, was obtained by dividing the Transport Infrastructure Investment (TII) (OECD, 2017) by the gain from the new technologies (Gain from EV/AV/eVTOL). The comparison with the Transport Infrastructure Investment formula (Figure 4) is presented below.

$$\%\ Increase\ TII = \left(\frac{TII}{Gain\ from\ (EV/AV/eVTOL)}\right)$$

The gain by vehicle was calculated using the above information. The main difference between the two technologies was obtained by taking the ICE cost and subtracting the EV/AV/eVTOL Cost. Dividing the result by the Motorization Rate by Country (MR) and adding the GDP per capita (The World Bank, 2021), we could estimate the increase of the GDP by vehicle when using EVs, AVs, and eVTOL technologies (Earned by EVs/AVs/eVTOLs). The formula is below.

$$Earned\ by\ (EV/AV/eVTOL) = \left(\frac{(ICEC\ Cost - EV/AV/eVTOL\ Cost)}{MR}\right) + GDP$$

The GDP Gain from Vehicle percentage was obtained using the Earned by (EV/AV/eVTOL) divided by the GDP and subtracted by 1. The following formula presents the % GDP Gain from Vehicle (Figure 2).

$$\%\ GDP\ Gain\ from\ Vehicle\ = \left(\frac{Earned\ by\ (EV/AV/eVTOL)}{GDP}\right) - 1$$

Thus, it was possible to present the **Economic Development** per capita in relation to technological leapfrogging. To calculate the EV/AV/eVTOL Increase per capita, the GDP per country (The World Bank, 2021) and the transport infrastructure investment (OECD, 2017) were used to compare the results.

The difference between the ICE cost and the EV/AV/eVTOL Cost was divided by Population by Country (PC) and then added to the GDP per capita (The World Bank, 2021). With that result, we calculate the increase of the GDP per capita when using EVs, AVs, and eVTOL technologies (EVs/AVs/eVTOLs Increase per capita). The formula is shown below.

$$EV/AV/eVTOL\ Increase\ per\ capita = \left(\frac{(ICEC\ Cost - EV/AV/eVTOL\ Cost)}{PC}\right) + GDP$$

To calculate the GDP Gain from Vehicle percentage, the EV/AV/eVTOL Increase per capita was divided by GDP and subtracted by 1. The following formula presents the % Gain from GDP per capita (Figure 3).

$$\%\ GDP\ per\ capita\ = \left(\frac{EV/AV/eVTOL\ Increase\ per\ capita}{GDP}\right) - 1$$

Finally, the calculations of **Greenhouse Gases Emission Reduction** were shown. To calculate the Total CO2 Emissions from Transport (CO2T), CO2 emissions from liquid fuel consumption (CO2L) (The World Bank, 2021) were multiplied by the percentage of CO2 emissions from transport (%CO2) (The World Bank, 2021), obtaining the total CO2T in kilotons **(Figure 5)**.

$$CO2T = CO2L \times \%CO2T$$

The CO2 Generated in the Production of Energy (CO2PE) spent on EVs, AVs, and eVTOLs was obtained by multiplying the Motorization Rate by Country (MR) (OICA, 2015) with the Annual KM Travelled by Country (Nation Master, 2014). The result was multiplied by the Total CO2 Generated from Electricity Production (TCO2E) in kilotons (1 g = 1 x 10-9 kt) (The World Bank, 2021) and by the EVs, AVs, or eVTOLs consumption (Cars US News, 2020; Fuel Economy, 2021; Statista, 2021; Uber Elevate, 2016).

$$CO2PE\ = MR \times KM \times TCO2E\ \times (EV/AV/eVTOL)$$

The CO2 reduction using EVs percentage (%) comes from multiplying the CO2 Generated in the Production of Energy (CO2PE) by CO2 emissions from transport (CPO2T) and subtracting the result from 1.

$$\%\ EV/AV/eVTOL\ CO2\ Transport\ Reduction = 1 - \left(\frac{CO2PE}{CO2T}\right)$$

The percentage of CO2 reduction compared to the Sustainable Development Goals (Figure 6) for each country (EVs/AVs/eVTOLs CO2 ODS Reduction) is given by the following formula (United Nations, 2021).

$$\%\ EVs/AVs/eVTOLs\ CO2\ ODS\ Reduction = \left(\frac{(CO2T - CO2E)}{CO2EC}\right)$$

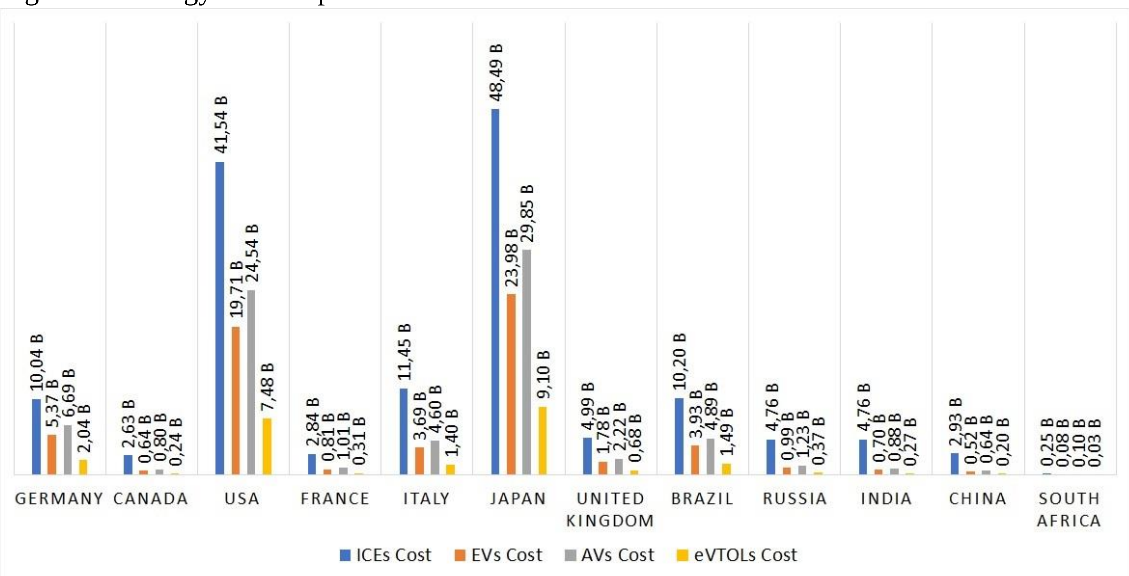
The calculations used the most recent data found in all databases mentioned in Table 1, and all data has been converted to corresponding units of measure. Besides the formulas, some calculations used the simple conversion of integers into percentages. This substitution shows and compares the results better. Simple calculations without formulas were used to compare the results between the G7 and the BRICS. The ICEs replacement by EVs/AVs/eVTOLs followed a 1 to 1 proportion, disregarding partial substitutions, i.e., total replacement. The purpose was to understand the structural characteristics and impacts of EVs, AVs, and eVTOLs technologies. To this end, the study aimed to consider the advantages of adopting these technologies as a driving factor in countries' economic growth. The discussions were built based on the countries' results.

Although the data used may be influenced by other factors not considered in this analysis, we consider the condition *ceteris paribus*, where all other factors are kept unchanged, thus assuming the variables chosen were the phenomenon's main determinants. Therefore, only one fuel source - gasoline, and one alternative energy source - electricity, with one production format for each and only one type of vehicle for each technology (ICE, EV, AV, and eVTOL) were considered. The data and results for each country were maintained separately. All results consider a one-year timeframe. The presented scenarios contribute to a better understanding of emerging technologies, their benefits for emerging countries, and how they can affect the economic and environmental context.

4. Results

The data analysis shows the G7 and BRICS countries' performances when ICE was totally replaced by electric-powered vehicles, disregarding technology replacement costs. Figure 1 shows G7 and BRICS countries regarding Energy Consumption. After, the benefits of inserting the new technologies are discussed.

Figure 1 – Energy Consumption of G7 and BRICS countries



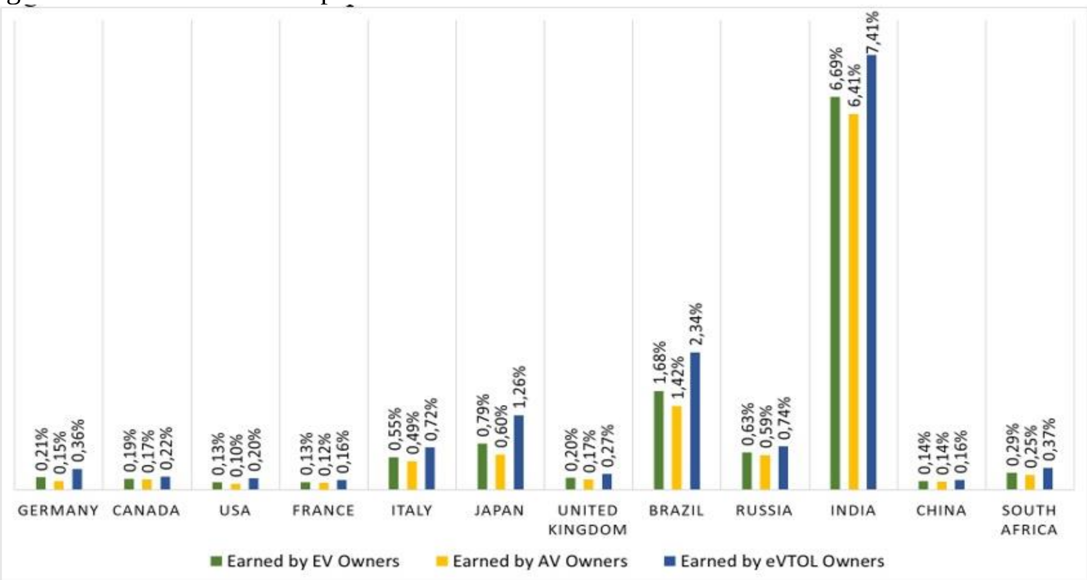
Source: Research Data.

The calculations for substituting Fossil Fuel with Electricity used the fleet by country data (OICA, 2015). ICEs consumption varies considerably within the G7 and BRICS, ranging from US$ 48 bi in Japan to US$ 246 mi in South Africa. In a total replacement scenario, all countries had considerable gains from fuel replacement and substantially reduced annual transportation costs.

The calculations on substituting ICEs used the countries' motorization rate (OICA, 2015), gasoline and electricity costs (Global Petrol Prices, 2020, 2021), vehicle consumption (Auto Express, 2020; Fuel Economy, 2021a, 2021b; Uber Elevate, 2016), and annual circulation (Nation Master, 2014), and were performed for each new technology. For EVs, the highest gains will be 85.20% for India and 75.50% for Canada. For AV technology, the gains will reach 81.58% in India and 69.50% in Canada, again, the highest in each group. For eVTOLs technology, considering the 42% decrease in air travel, India would achieve 94.39%, and Canada would have 90.71% in benefits. Germany will reach 79.69%, the smallest gain among all countries. This data reveals positive benefits in transportation in the replacement of the current source of fossil fuels with electricity.

Considerable differences were found regarding Economic Development based on the country’s GDP per capita (The World Bank, 2021). The G7 countries have an average income of U$ 44.89 thousand, higher than BRICS, with an average of U$ 7.73 thousand. Figure 2 shows the economic gains in each vehicle substitution after subtracting the ICEs cost from the cost of EVs, AVs, and eVTOLs.

Figure 2 – Economic Development GDP Gain from Vehicle

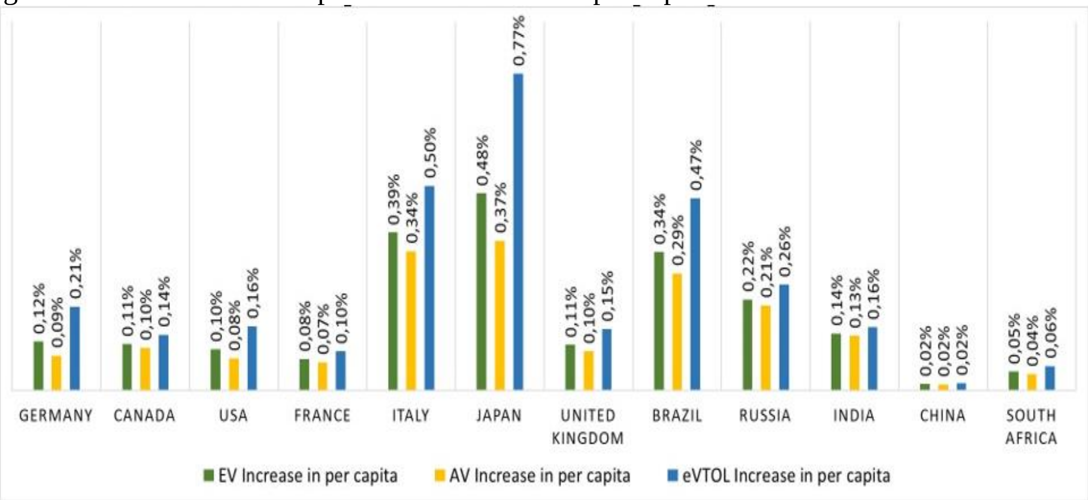


Source: Research Data.

India had the highest per capita gain among all countries, with 6.69% for EVs, 6.41% for AVs, and 7.41% for eVTOLs. Brazil also showed an increase in GDP in all modes, reaching 1.68% for EVs, 1.42% for AVs, and 2.34% for eVTOLs. Although almost all increases in countries' GDP are less than 1%, for eVTOL technology, Japan attained a 1.26% GDP increase.

All BRICS average growth is superior to the G7 results. The average growth of the G7 countries was 0.31% for EVs, 0.26% for AVs, and 0.46% for eVTOLs, while the BRICS growth was 1.89% for EVs, 1.76% for AVs, and 2.20% for eVTOLs. India and Brazil's high results are pulling up these data. The average growth rate of developed countries is expected to be lower because they already have more stable economies.

Figure 3 – Economic Development Gain from GDP per capita



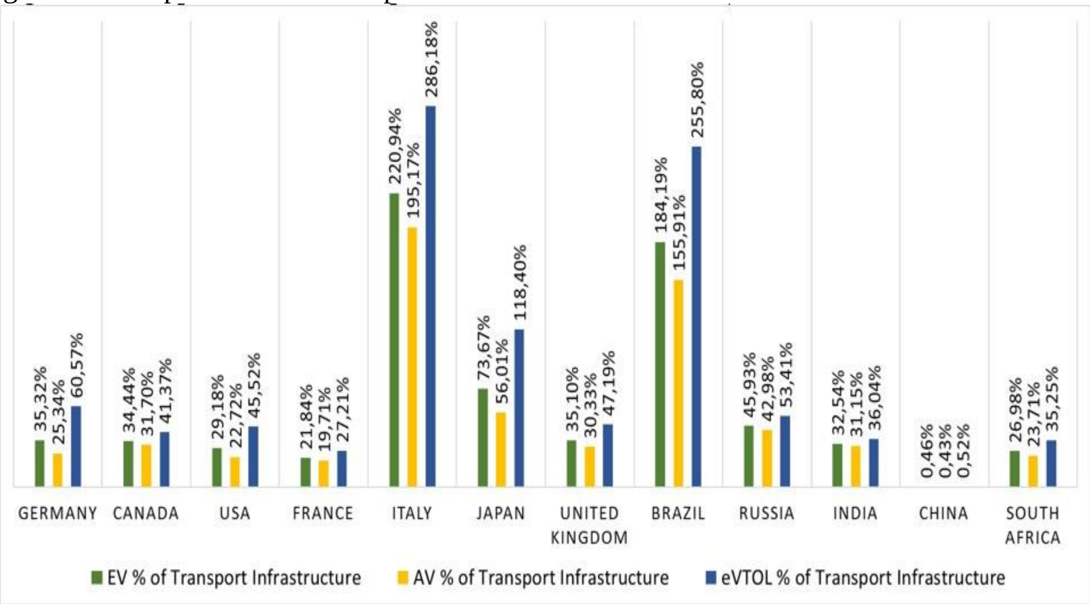
Source: Research Data.

Figure 3 shows the GDP per capita gains by country and technology. The highest percentages in the G7 and BRICS were Japan and Brazil. Japan reached 0.48% for EVs, 0.37% for AVs, and 0.77% for eVTOLs, while Brazil attained 0.34% for EVs, 0.29% for AVs, and 0.47% for eVTOLs. It is worth mentioning that Brazil's results were superior to most of the G7 countries, except for Italy and Japan. China presented the lowest growth of all countries, with 0.20% for all three technologies, and its low result was due to its high population density, which attenuates the economic gain.

Unlike the growth averages per vehicle, where the BRICS countries had the best results, the average GDP per capita gain was higher in the G7. The G7 average growth was 0.20% for EVS, 0.16% for AVs, and 0.29% for eVTOLs, while the BRICS showed 0.15% for EVS, 0.14

% for AVs, and 0.19% for eVTOLs. Figure 4 compares the amount saved by countries by replacing EVs, AVs, and eVTOLs technologies and infrastructure investments.

Figure 4 – Comparison with Transport Infrastructure Investment



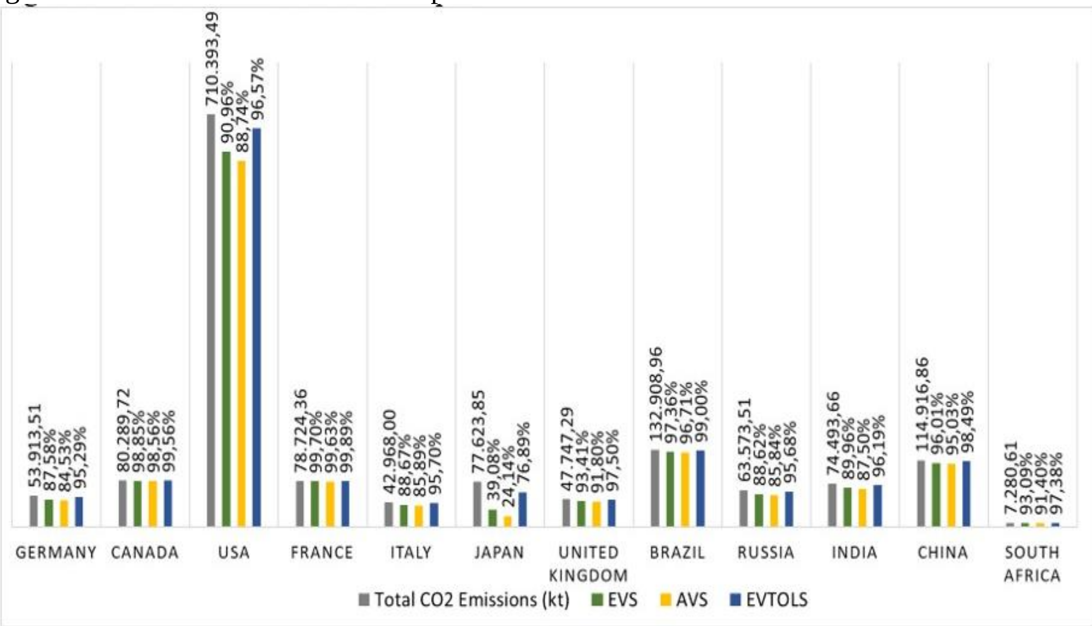
Source: Research Data.

The data show discrepancies in countries' transport infrastructure investments (OECD, 2017). The G7 countries invest an average of U$ 21.29 billion, with the USA being the highest, reaching U$ 74.82 billion, and Italy, the lowest, with U$ 3.51 bi. The BRICS average investment was U$ 110.73 billion. This high number is due to substantial investment from China, with U$ 528.99 billion. Excluding China, the BRICS average is U$ 6.17 billion, with the second-largest investment from India, U$ 12.46 billion, and the lowest investment from South Africa, U$ 0.61 billion.

Comparing these data with the benefits from new technological replacement showed that all countries had considerable gains, with the best results in Italy and Brazil, respectively, in G7 and BRICS. Italy's gains compared to investments in transport infrastructure were 220.94% for EVs, 195.17% for AVs, and 286.18% for eVTOLs. Brazil reached 184.19% for EVs, 155.91% for AVs, and 255.80% for eVTOLs. China had the lowest values, 0.46 for EVs, 0.43 for AVs, and 0.52% for eVTOLs. However, these low numbers from China are due to the higher amount invested in transport infrastructure than in other countries.

Figure 5 presents the benefits of replacing fossil fuel for electricity, i.e., the CO2 emissions gains by country (kt) and technology (The World Bank, 2021).

Figure 5 – CO2 Emissions from Transport



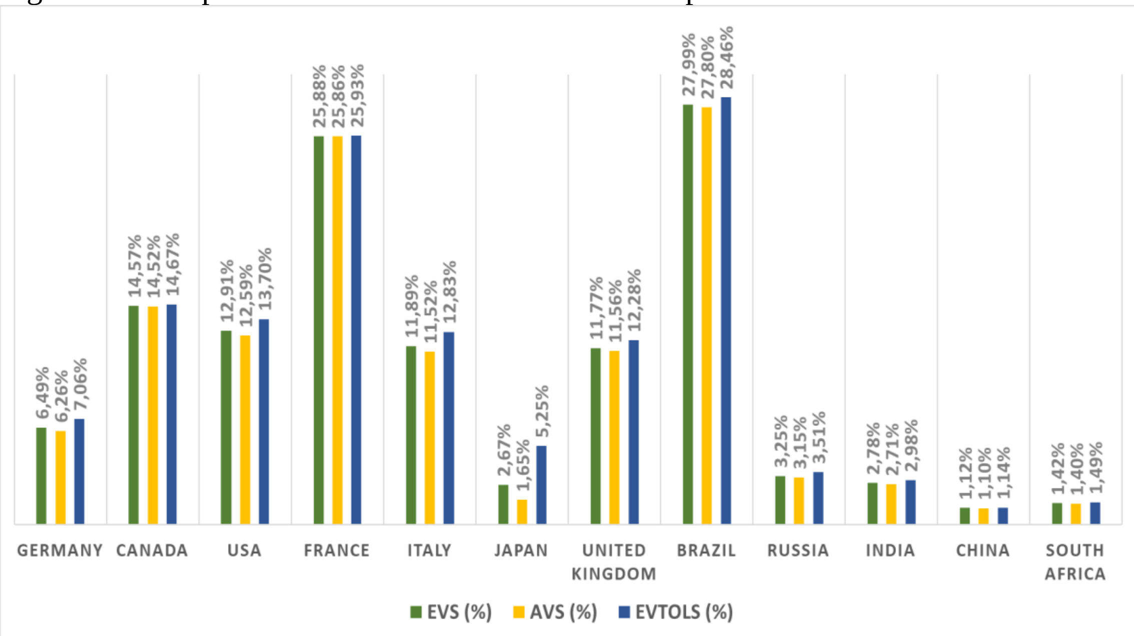
Source: Research Data.

Tailpipe emissions from EVs, AVs, and eVTOLs technologies were disregarded, so only the emissions from producing electricity for recharging vehicles were considered. France in G7 and Brazil in BRICS had the most significant reductions in emissions from transportation. France reached 99.70% for EVs, 99.63% for AVs, and 99.89% for eVTOLs, while Brazil achieved 97.36% for EVs, 96.71% for AVs, and 99.00% for eVTOLs. Among the G7 countries, the USA has the highest transport emissions at more than 710 thousand kt and could reduce up to 90.96% by replacing the fleet with EVs, 88.74% with AVs, and 96.57% with eVTOLs. G7 average emissions are 155.95 thousand kt, while the BRICS are 78.63 thousand kt. Thus, G7 will benefit more from fleet replacement.

Comparing total emissions by country (The World Bank, 2021), Figure 6 shows the countries' reduction percentage when using EVs, AVs, and eVTOLs technologies, compared to the 45% reduction in total emissions suggested by the Sustainable Development Goals (United Nations, 2021).

Figure 6 shows the emissions reduction by country when replacing ICEs with EVs, AVs, and eVTOLs technologies. These data must be compared with the 45% reductions in total emissions suggested by the Sustainable Development Goals (United Nations, 2021).

Figure 6 – Comparison with CO2 Sustainable Development Goals



Source: Research Data.

The replacement of the current fleet by EVs, AVs, and eVTOLs could help G7 and BRICS countries to reach the 45% emissions reductions suggested by the Sustainable Development Goals (United Nations, 2021). For instance, France in the G7 would reduce emissions by 25.88% for EVs, 25.86% for AVs, and 25.93% for eVTOLs, while Brazil would see a 27.99% reduction for EVs, 27.80% for AVs, and 28.46% for eVTOLs. Note that France and Brazil have the lowest total emissions within each group.

The USA has the highest total emissions in the G7 with 5.00 thousand kt, while China is at 9.89 thousand kt in the BRICS. The USA will reduce emissions by 12.91% for EVs, 12.59% for AVs, and 13.70% for eVTOLs, and China will reduce emissions by 1.12% for EVs, 1.10% for AVs, and 1.14% for eVTOLs.

G7 countries would have better results due to their larger vehicle fleets, GDP, CO2 emissions, and technology patents. When replacing fossil fuel technologies with electricity, G7 will benefit more financially and in emissions. In turn, most of the BRICS do not have the same consumption patterns as the G7, leading to lower benefits.

There is no direct indication that technology development is related to a country's performance. Also, other criteria and economic factors may affect such performance. However, in the next section, we assume that technology plays a central role in economic development (Schniederjans, 2017), and the changes in transport scenarios may enable new development opportunities.

5. Scenario Development

From the results described above, it was possible to summarise the study's main results in Table 2, which are discussed in this section.

Table 2 – Main results of the study.

Analysis Category	Main Results	Discussions and Contributions of the Technological Leapfrog
Transport Energy Consumption	• G7 ICE cost 3.81 times higher than BRICS; • G7 has a consumption gain 6.43 times greater than BRICS.	• The measure of efficiency tends to be the differential for the decision to adopt new technologies; • Positive results could spur the arrival of EVs, AVs and eVTOLs.
Economical Development	• EVs: GDP increase of 1.89% for the BRICS countries and 0.31% for the G7; • AVs: Average gain 1.76% for the BRICS and 0.26% for the G7; • eVTOLs: Increase of 2.20% for BRICS and 0.46% for G7.	• EVs, AVs and eVTOLs can make BRICS countries more globally competitive; • Economic results prove to be viable for emerging countries to develop the technological leap.
Greenhouse Gases Emission Reduction	• G7: Average emission reduction gain of 85.46% for EVs, 81.90% for AVs and 94.49% for eVTOLs; • BRICS: Average emission reduction gain 93.01% for EVs, 91.29% for AVs and 94.35% for eVTOLs.	• Impact on reducing CO2 emissions for EVs, AVs and eVTOLs in all countries.
Market Development	• EVs: Change in supply pattern requiring investments in recharging stations; • AVs: Change in consumption pattern, vehicle sharing, and increased travel safety; • eVTOLs: Air travel with shorter distances, greater reduction of emissions and fuel consumption.	• Results with gains in economic development of countries; • Need for local adjustments such as country-specific regulations and infrastructure.

Source: Research Data.

Based on the data presented, we can make inferences about replacing existing fossil fuel-based transportation technologies with EVs, AVs, and eVTOLs. The scenarios and inferences consider the Energy Consumption, Economic Development, and Reduction of Greenhouse Gas Emissions categories, and the discussions are based on those categories.

5.1. Transport Energy Consumption

Japan (77 million), China (162 million), and the USA (264 million vehicles) are the countries with the highest motorization rate, which impacts the ICEs values. Japan had the highest ICE cost at US$ 48 billion, impacted by the high fuel cost due to the high circulation mileage per vehicle. Even with the lowest fuel cost in the sample, the USA was impacted by the highest vehicle mileage, reaching the second-highest ICE cost at US$ 41 billion. With lower fuel costs and low circulation kilometres, China had one of the lowest ICE costs at US$ 2.9 billion. The results show that fuel costs were cut by at least 50% when using electricity for EVs, AVs, and eVTOLs. That is consistent with the literature, which suggests that a proper mix of vehicle, fuel, and mileage will lead to sustainable effects (Yang *et al.*, 2020).

The average ICE cost for the G7 is 3.81 times higher than for the BRICS countries. The G7 countries would have savings in fuel consumption 6.43 times greater than the BRICS countries for all three technologies. India had the best results in replacing the technologies, raising the BRICS countries' average. However, as presented in the Indian scenario, changing fuel sources is a viable path for emerging economies. As presented by the literature (Skeete, 2018), although transitioning to a new mobility system is a complex challenge (Mello *et al.*, 2021), it is possible to infer that EVs, AVs, and eVTOLs can trigger a profound and transformative transition in the automotive industry. The scenarios for these potentially disruptive technologies are promising since the positive results of replacing fossil fuels with renewable sources can boost the arrival of EVs, AVs, and eVTOLs.

5.2. Economic Development

Except for EVs that are already operational in more developed markets and some emerging markets (Wang *et al.*, 2018), there is still no complete information on the AVs and eVTOLs' operational costs. Thus, as the relationship between technological progress and economic growth is positive (Schniederjans, 2017), it is possible to notice a direct gain from replacing the energy matrix. With technological change, the technologies could provide countries with a GDP gain for each vehicle. EVs could provide an average gain of 1.89% for BRICS against 0.31% for G7 countries. The AVs could allow 1.76% on average for the BRICS against 0.26% for the G7. EVTOLs would enable an average gain of 2.20% for BRICS against 0.46% for the G7. The average per capita gain in the G7 was higher than the BRICS countries due to China and India's high population densities.

Also, considering countries' investment in infrastructure and technological replacement's benefits, the gain becomes an essential driver of the technologies. EVs could provide an average reduction of 44.28% for the G7 and 54.03% for the BRICS; AVs could provide an average reduction of 35.07% for the G7 and 49.09% for the BRICS; and eVTOLs could provide an average reduction of 67.59% for the G7 and 66.54% for the BRICS. Corroborating with the literature (Kassens-Noor *et al.*, 2021; Silva *et al.*, 2022), these criteria are a driving force for the diffusion of EV technologies, but other criteria may be considered for AVs and eVTOLs. As pointed out in the literature (Faghih *et al.*, 2018; Giri *et al.*, 2021; Mello *et al.*, 2021; Wang and Zheng, 2022) and reinforced in this study, it is also possible to infer that disruptive innovation leapfrogging for EVs, AVs, and eVTOLs technologies could change the pattern set by current technologies, feeding the emerging BRICS economies, making them more globally competitive.

AVs' automation technology allows vehicles to be shared, reducing mileage costs by approximately three times and can reduce the cost of ownership by up to 10 times (Burns *et al.*, 2013). AVs can further reduce road maintenance and accident costs through efficient automation. EVTOLs can reduce transport costs due to sharing and the ability to fly over land, bringing up to 42% more efficiency (Uber Elevate, 2016). Transport is central to driving productivity and influencing innovation activities (Amankwah-Amoah, 2015; Durst and Leyer, 2022; Schniederjans, 2017; Seum *et al.*, 2020). The study indicates that the latest disruptive innovations may promote technological leapfrogging for emerging economies and foster economic development.

5.3. Sustainable Results

The replacement of fossil fuels with electricity, ceteris paribus, will bring to the G7 countries the following average emission reduction: 85.46% for EVs, 81.90% for AVs, and 94.49% for EVTOLs. In turn, the BRICS countries would have reductions of 93.01% for EVs, 91.29% for AVs, and 94.35% for eVTOLs. This corroborates the literature recommending substituting transport fuel sources with electricity to help countries attain benefits and develop transport capacities, resources, and market power (Amankwah-Amoah and Debrah, 2014). Simulations showed that autonomous transportation mobility could be profitable (Richter et al., 2021) and reduce greenhouse gas emissions (Yan et al., 2018) in selected scenarios. Also, alternate fuels promise to reduce pollutant emissions from transport and bring environmental and economic benefits (Ala *et al.*, 2021).

Countries must focus on green technology or clean energy (Raghutla and Chittedi, 2021) to achieve economic growth. This study agrees with the literature asserting that changing current modalities to EVs transportation would bring benefits (Brown *et al.*, 2014; Wadud and Anable, 2016). Moreover, AVs would allow resource sharing and route efficiency. Companies in the market (Booz Allen Hamilton, 2018; Uber Elevate, 2016) also expressed that eVTOLs would be beneficial due to reducing mileage and, consequently, less fuel usage. Some literature also states that the relationship between development and the environment is possible.

Developed and developing nations can use technological advances to reduce CO2 emissions (Kamoun *et al.*, 2020; Mello *et al.*, 2021; Njoroge *et al.*, 2019).

5.4. Market Development

This study assumes that technological performance is a productivity and economic driver (Giri *et al.*, 2021; Schniederjans, 2017; Wang and Zheng, 2022) and that infrastructure and transport technologies are essential economic growth drivers (Amankwah-Amoah *et al.*, 2021; Kyriacou *et al.*, 2018). The G7 countries' average investment in transport infrastructure was 0.38% of GDP, while BRICS countries, disregarding China, invested only 0.15% of GDP. Considering the GDP gross discrepancy between these groups, the G7 investment was 1.34 times greater than BRICS considering China and 3.35 times greater excluding China. With these results, it is possible to infer that disruptive innovation of transportation mobility technologies can unfold opportunities for countries' economic development.

China's total investments in transport infrastructure are three times higher than G7 countries combined (OECD, 2017), with the second highest GDP (The World Bank, 2021). Investment in transport infrastructure is known to affect economic development positively (Kyriacou et al., 2018; Seum et al., 2020), yet emerging economies often lack investments (Amankwah-Amoah et al., 2021; Kapidani and Luci, 2019). Partnerships between the Global North and less developed countries can bring mutual learning and benefits since the former are struggling with fossil fuel scarcity (Chabrol, 2016). The results allow us to infer that the insertion of EVs, AVs, and eVTOLs in emerging markets changes this state, triggering opportunities within the technological environment.

EVs and AVs demand recharging stations on the roads and, therefore, adjustments in energy standards, as some countries' energy matrixes may not support the new demand (Morrissey *et al.*, 2020; Wadud and Anable, 2016). However, AVs tend to offer Mobility-as-a-Service (MaaS) (Hensher, 2017), leaving recharge to mobility providers. Unlike the ownership for EV diffusion, the AV scenarios for MaaS consider vehicle sharing (Merfeld *et al.*, 2019; Silva *et al.*, 2022). Since eVTOLs' electric batteries would be the same as EVs and AVs, fuel consumption, emissions, and safety savings could be equal or greater (Booz Allen Hamilton, 2018; Uber Elevate, 2016). Those changes could reduce the vehicle fleet and congestion (Fagnant and Kockelman, 2015), alter transport patterns, and decrease fuel consumption (Brown *et al.*, 2014), emissions (Wadud and Anable, 2016), and accidents (Fagnant and Kockelman, 2015).

The new transportation technologies demand investments with distinct return timeframes. Depending on technological conditions, user acceptance, and legislation, costs could be lowered, leading to demand growth (Booz Allen Hamilton, 2018; Silva *et al.*, 2022). Our inferences corroborate with the literature where the potentially disruptive innovation technologies such as EVs, AVs, and eVTOLs can introduce new transport possibilities (Cohen *et al.*, 2021; Skeete, 2018), triggering a great change in the automotive industry and the transportation mobility market (Skeete, 2018), leading to a growth in the sector (Christensen *et al.*, 2001; Silva and Grützmann, 2022).

6. Discussion

One of the great innovations in mobility is the innovation of EVs, AVs, and eVTOLs technologies. This study shows that EVs, AVs, and eVTOLs can trigger a deep and transformative change in the automotive industry and the market (Skeete, 2018). Concerning Transport Energy Consumption, it is noteworthy that energy efficiency may first attract developed countries. Alternate and efficient technologies such as EVs, AVs, and EVTOLs will help respond to climate change by increasing clean and renewable energy (Gu *et al.*, 2018). However, this study infers that innovation technologies might also prove advantageous to emerging markets to reduce carbon emissions with the help of capital and technology (Raghutla and Chittedi, 2021), allowing high levels of growth. Government support for companies is vital to ecosystem development (Stone *et al.*, 2020), and public-supported research can help to understand the implications of automated driving to prevent adverse outcomes and follow positive ones (Fagnant and Kockelman, 2015).

As indicated in the Economic Development section, the scenarios for inserting EVs, AVs, and eVTOLs technology are promising for emerging markets. This study aligns with the existing literature (Raghutla and Chittedi, 2021), asserting that technology insertion can enable emerging countries to approach or surpass developed countries. AVs and eVTOLs are expected to spread as their costs become lower. This corroborates with the literature (Afrifa *et al.*, 2020; Amankwah-Amoah *et al.*, 2021; Kyriacou *et al.*, 2018; Marletto, 2019; Mello *et al.*, 2021). It is possible to infer that emerging countries could benefit from the growth of transport and public investment for social, environmental, and economic development. The economic dimension shows emerging countries' viability in pursuing this technological leapfrogging.

Regarding Sustainable Results, technological innovation and energy are critical for sustainable development (Raghutla and Chittedi, 2021), thus adopting new power-sourced technologies is essential for reducing emissions (Cowan *et al.*, 2014; Kamoun *et al.*, 2020; Mello *et al.*, 2021). Electricity, automation, and sharing seem to be intertwined in future mobility (Sovacool *et al.*, 2021). Some literature asserts that most emerging countries cannot handle their

CO_2 emission levels, so new technologies can be used to boost sustainable economic development (Amankwah-Amoah *et al.*, 2021; Raghutla and Chittedi, 2021). Even if the introduction of pre-mature technologies is not without potential liabilities, the results allow us to infer that using EVs, AVs, and eVTOLs technologies can lead to significant accomplishments in CO_2 reduction, providing an opportunity for developing countries to reach UN's Sustainable Development Goals (SDG), mainly Goal 11 related to Sustainable Cities and Communities.

New technologies can change countries' value chains, requiring national regulations, infrastructure, and complementary technologies and platforms (Silva and Grützmann, 2022). Countries replacing technologies could leap forward, achieving transport, economic, CO_2 reduction, and social benefits. In line with the literature on disruptive innovations, new markets creation, and technological leapfrogging (Afrifa et al., 2020; Christensen et al., 2018; Dedehayir et al., 2018; Palmié et al., 2019), it is possible to infer that the EVs, AVs, and eVTOLs allow emerging economies to create new markets and reach developed countries standards. Besides technology localization, other investments will be necessary to build new markets, offering opportunities for a technological leapfrog in infrastructure and transportation, leading to mobility, economic development, and sustainability gains.

This work concurs with past studies that additional research is needed to help minimise the technological gap between emerging and developed countries (Amankwah-Amoah *et al.*, 2021; Kapidani and Luci, 2019; Niebel, 2018; Ofinade and Alola, 2022). The potential disruptive technologies tend to generate new value propositions (Christensen *et al.*, 2018; Dedehayir *et al.*, 2018; Palmié *et al.*, 2019), enabling economic, environmental, and social benefits for countries acting first.

As inferred in this study and following the literature, emerging countries can get closer to the major world powers through technological leapfrogging (Jin *et al.*, 2018) by finding cooperation opportunities (Heiden, 2016; Sovacool *et al.*, 2021). Therefore, the environmental leapfrogging perspective can help investigate the ICE's substitution for new technologies. This study also corroborates that partnerships among research institutions from developed and emerging countries could enhance absorptive capacities, which are crucial to leapfrogging (Afawubo and Noglo, 2022; Heiden, 2016).

6.1. Theoretical Implications and Contributions

The authors could not find studies considering EVs, AVs, and eVTOLs as opportunities for countries to leapfrog in the transportation mobility sector on Emerald, Science Direct, Scopus, and Web of Science. This work contributes to the literature on those potentially disruptive innovations (Christensen *et al.*, 2001, 2018; Yaghmaie and Vanhaverbeke, 2019), investigating their benefits for developed and emerging economies. The results also endorse research with the same scope linked to fossil fuel substitution. This study's novelty is presenting the technological, economic, and sustainable leapfrog to EVs, AVs, and eVTOLs. Technological leapfrog theory is likewise reinforced since the results show transportation mobility advantages and potentially disruptive innovations replacing ICEs.

This paper further contributes to transport, economic, and sustainable development studies, raising awareness about transportation mobility's future technological benefits and impacts on society. The landscape presented here can stimulate new studies comparing specific technologies in their markets to further the leapfrog theory in developed and emerging countries. Likewise, this work suggests new comparative studies among potentially disruptive innovations since it recognizes the benefits of leapfrogging in transportation mobility.

This study also contributes by presenting the opportunity technological innovations have to disrupt the market. We use the particular (and futuristic) case of the new transport technologies of EVs, AVs, and eVTOLs to present the environmental, economic, and social impacts. Extracting from a particular case to a broader scope, it is possible to infer that new technologies can be an opportunity to disrupt and change market trajectories toward the technological leap. In addition to transport impacts, the inferences and scenarios presented here are useful for raising other impacts and concerns with new technologies.

Research avenues are open on the new concerns that society will have, as well as the legal aspects that public policymakers and legislators need to solve. Infrastructure faces issues where negotiations are necessary to implement projects such as urbanism coverage for an entire supply point network, accessing transport modes, and transforming the land and aerial landscape. Moreover, access, accessibility, and impacts on social organization structure will change, altering the social environment. Thus, it is necessary to think of solutions to be disseminated at all social levels. There are also geographic impact issues, where new technologies will allow users to move differently, facilitating the transition between global territories. These and other impacts are possible sources of study for the disruption arising from new technologies in the market. Specifically, EVs, AVs, and eVTOLs are technologies in an advanced development and market state, impacting transportation modalities and the entire market, where several other aspects of this disruptive innovation must be deepened.

The methodological contribution involves using current data to prospect future technological results by inserting innovative technologies in the current market comparing G7 and BRICS countries. The research confirms the literature using calculations from open and widely available data sources to compare distinct inferences and scenarios.

6.2. Practical Implications and Contributions

This article brings an economic contribution by estimating potential energy savings, GDP increase, and CO2 emissions reductions for each technology per country in the G7 and BRICS, noticing the greatest latent benefits. On the market disruption side, these results are useful for operators and new entrants to the transportation mobility market to protect their markets or open up new opportunities. The study's estimates can be useful to companies from the G7 that seek partnerships to explore demand and market development in the most promising BRICS countries.

This study corroborates the advantages of replacing fossil fuel-based technologies with sustainable alternatives. From a practical and managerial perspective, organizations can use the inferences and scenarios for EVs, AVs, and eVTOLs to understand incipient markets on the sustainable, economical, and social dimensions. A firm can benefit from leapfrogging to pursue advantageous positions or to protect from newcomers by changing its value proposition. Since literature denotes the interweaving of electricity, automation, and sharing, innovation ecosystems can be better positioned to deal with the complexity. Economic growth and greenhouse gas emission reduction results suggest that innovation technologies' value propositions should be linked to environmental and economic dimensions. The comparison between developed and emerging countries can incentivize emerging countries' technological, economic, and sustainable transformation.

The positive social outcomes from the technological leapfrog stand as a social contribution. Cautiously, the transportation mobility leapfrog may benefit infrastructure, economy, and sustainability for the G7 and BRICS. The results subsidize policymakers and government bodies to foster initiatives or projects to accelerate new transport technologies, reducing CO2 emissions and enabling economic gains and sustainable development.

Finally, this study contributes to understanding upcoming scenarios of emerging technologies for G7 and BRICS policymakers and public managers. Further, it inspires the development of these potentially disruptive technologies in the ecosystem for technological, economic, and sustainable growth opportunities. Governments can collect benefits from changing regulations and fostering investments in green energy towards SDG goals.

7. Conclusion

The forecasts for the insertion of EVs, AVs, and eVTOLs technologies in G7 and BRICS countries are promising. This study aimed to analyse the technological, economic, and environmental impacts of the potentially disruptive innovations in the transportation mobility market. Leapfrogging from potentially disruptive technologies can bring sustainability and economic growth to the G7 and the BRICS, where efficiency stimulates technological adoption. The replacement of existing technologies by EVs, AVs, and EVTOLs could also increase GDP. Likewise, both groups would benefit from CO2 emission reduction. The results show favourable conditions for technological replacement and the development of new markets for the technologies mentioned above.

Finally, this study presented a brief transport, environmental, and economic perspective on new transportation technologies. Despite the initial investment, developed and emerging countries can aim for technological leapfrogging and thus promote remarkable economic and sustainable development. This study’s contribution shows technological innovations’ opportunity to disrupt the market. In this study, transport disruptions bring technologies economically and have environmental benefits by replacing fossil fuels. It is possible to conclude that innovation and technology diffusion trigger growth. Thus, early investments in these disruptive technologies could be an opportunity to create disruption and change the trajectory of the ecosystem toward the technological leap. In addition to transport, economic, and environmental impacts, this study also points to several research avenues open to analysing technological disruptions, such as legal, infrastructure, urbanism, accessibility, social, land, and air impacts.

7.1. Limitations and Future Research

This study has clear limitations as it uses secondary sources' available data, even the most recent. Also, it considers *ceteris paribus*, assuming the chosen variables were the main determinants of the phenomenon. Further research can compare country-specific data using simulation methods with additional variables. Those variables can be collected from systematic literature reviews encompassing transportation mobility, smart mobility, sustainability, and economic development in developed and developing countries. Besides newer data sources, new methods such as Delphi and machine learning may help provide new models and bring new insights.

Another limitation was disregarding the current fossil fuel technologies substitution costs by electric-powered vehicles. These costs would help to understand whether the replacement is advantageous. Future studies can delve into the cost comparisons of introducing new technologies and maintaining existing technologies, realizing how emerging and developed countries could bridge their infrastructure gaps to make a technological leapfrog. Also, since EVs, AVs, and EVTOLs are growing, and their adoption rate tends to increase, future studies can simulate partial adoption rates (25%, 50%, or 75%) for each technology to investigate scenarios where ICEs coexist with a mix of new technologies.

Transitioning to sustainable mobility can be long, costly, and complex, so changing regulations and certifications were not considered here. New research is crucial to understand the stakeholders' role, especially for public transportation. Hence, forthcoming studies could assess social and legal frameworks to identify critical barriers to the diffusion of new transportation technology. Forthcoming marketing studies and technology acceptance models may help understand customer attitudes and early adopters towards new transportation mobility technologies.

The innovation ecosystems approach is a promising study field to become aware of actors, activities, artifacts, and relations linked to EVs, AVs, and EVTOLs, mapping their expansion. In this sense, the disruptive innovations' impact on the ecosystem transformation and the existing transport system value proposition are possible gaps in understanding this market development. Future studies may prospect business ecosystem scenarios to better understand and position the disruption. A study in a university campus or a small community implementing complete replacement by new transport technologies could bring data to confirm broader applicability.

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ARTICLE 4 – THE DYNAMICS OF VALUE PROPOSITION WITHIN A DISRUPTIVE ECOSYSTEM: THE CASE OF DISRUPTIVE TRANSPORTATION MOBILITY TECHNOLOGIES

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An innovation will get traction only if it helps people get something
that they're already doing in their lives done better.
(Clayton M. Christensen).

THE DYNAMICS OF VALUE PROPOSITION WITHIN A DISRUPTIVE ECOSYSTEM: THE CASE OF DISRUPTIVE TRANSPORTATION MOBILITY TECHNOLOGIES

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André Grutzmann

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Abstract:
Purpose – To explore the value proposition dynamics evolution of potentially disruptive innovations in the transportation mobility ecosystem.
Design/methodology/approach – A document analysis of reports and websites from several specialized consulting firms and technology development businesses was carried out to build a longitudinal case study within the Disruptive Ecosystem Evolution model.
Findings – The results show an evolution of the innovation ecosystem in the face of disruptions, as actors collaborate and co-evolve within the ecosystem, fostering technology development. This dynamic value proposition plays out across the ecosystem as market players and businesses adapt to disruption.
Research limitations/implications – This study is limited to secondary data and content analysis. The study contributes to the literature with an understanding of the ecosystem's value proposition for the development of disruptive technology and the interpretation of the value proposition promoted in the new ecosystem.
Practical implications – This study presents the new value proposition of the evolution of the transportation mobility ecosystem. This provides a picture of how disruptive technologies affect and reconfigure the existing value. This study also contributes to a dynamic of value transition to new technologies and the adaptation to the new ecosystem and emerging market.
Originality/value – This is the first study to analyze the transition of the value proposition in disruptive transportation mobility technologies.
Keywords – Disruptive Innovation; Ecosystem; Value Proposition; Transportation Mobility.

1. Introduction

Businesses are constantly searching for new opportunities to create value propositions within the competitive global setting. This growing number of propositions fuels the development of innovations and entire ecosystems to capture these opportunities (Christensen et al., 2018; Kumaraswamy et al., 2018; Palmié et al., 2019). With the power to impact markets, these disruptions can even change the entire value proposition of the ecosystem.

In innovation ecosystems, businesses develop actions, decisions, and investments in a collaborative and complementary way to create value from technical or business innovation that is impossible in isolation (Adner, 2006; Holgersson et al., 2022; Yaghmaie & Vanhaverbeke, 2019). Such innovation ecosystems have the ability to impact markets

(Granstrand & Holgersson, 2020; Palmié et al., 2019), as studies on disruptive innovation point to the impact of new technologies and/or business models on the value structure of an existing ecosystem (Adner & Lieberman, 2021; Christensen et al., 2018). The ecosystem theory indicates that technological advancement and market needs drive ecosystem transformation through value creation (Oghazi et al., 2022), where the impact of disruptive innovation can only occur when the entire ecosystem is considered (Williams, 2014). In this sense, technological transitions are significant long-term technological changes that reconfigure the industry (Geels, 2002) and must consider within the scope of ecosystems.

The mobility sector is one of the most innovative ecosystems today: the standard of internal combustion engines (ICEs) suffers from the impact of new technologies for electric vehicles (EVs) that are beginning to enter the market; autonomous vehicles (AVs) are still in the testing phase; and even electric vertical take-off and landing vehicles (eVTOL), bringing a new aerial perspective to transportation mobility. According to Silva et al. (2022 – Article 2), the strategic perspective of businesses is moving towards the development of these technologies, raising the importance of investigating the change in the value proposition of these technologies in the ecosystem and understanding the change in the value proposition in the face of possible disruption.

Multiple authors have suggested that disruption can transform an ecosystem's entire initial value proposition and value chain (e.g. Christensen, 2006; Christensen et al., 2018; Dedehayir; Ortt & Seppänen, 2017; Jacobides; Cennamo & Gawer, 2018). When disruptive innovation drives a rapidly changing environment, one should not neglect the power of the forces that build and transform ecosystems (Kumaraswamy et al., 2018; Palmié et al., 2019). However, the academic literature has not yet provided a clear picture of the impact of disruptive innovation on the value proposition. There is a lack of studies specifically on transportation mobility – only a few studies have sought to understand how disruptive innovations can disrupt existing industries and build new ecosystems (Ansari et al., 2016; Oghazi et al., 2022; Ozalp et al., 2018; Pushpananthan & Elmquist, 2022). Such disruptive innovations and technological advances are responses to market needs that drive ecosystem transformation through the creation of new value (Oghazi et al., 2022), and generate creative destruction in an existing ecosystem (Clarke, 2019; Dedehayir et al., 2017; Nicolaï & Faucheux, 2015). This evolution of a new disruptive ecosystem, based on new technologies and a new business model, is in itself worthy of research (Christensen et al., 2015; Palmié et al., 2019; Pushpananthan & Elmquist, 2022).

Starting from the possibility of a disruption in the transportation mobility ecosystem, this study questions how the dynamics of evolution of the value proposition of a disruptive ecosystem occur? We propose that disruptive innovations can go beyond just changing the initial value proposition and turning it into a "dynamic value proposition". Thus, the objective of this study proposes to explore the value proposition dynamics evolution of potentially disruptive innovations in the transportation mobility ecosystem. We will employ the Disruptive Ecosystem Evolution model by Silva and Grützmann (2022), which focuses on the disruptive technological change to an existing ecosystem, and use the model to carry out a longitudinal case study of the transition dynamics of the value proposition of transportation mobility technologies.

The core contributions to the literature come from a deeper understanding of the ecosystem's value proposition for developing new potentially disruptive technology within the existing transportation mobility ecosystem. As the value proposition is central to the ecosystem and its transformation (Oghazi et al., 2022), this study also addresses the ecosystem where disruptive innovation occurs, which can help interpret and analyze the differentiated value proposition promoted in the new ecosystem. In this case, as a practical contribution, this study presents the new value proposition of the evolution of the transportation mobility ecosystem. This information would provide a broader picture of how disruptive technologies and business models will affect established ecosystems, leading to the reconfiguration of existing value. This study also seeks to contribute to the management literature with a dynamic of value transition to new technologies and the adaptation of businesses to the new ecosystem and market that emerge.

2. Theoretical Background

2.1. Disruptive Innovation and Innovation Ecosystems

The theory of disruptive technology explores how innovations with different characteristics have come to outperform dominant technologies in the market (Christensen, 1997; Christensen et al., 2018). We can describe business models for disruptive innovations as strategic architectures that redefine the meaning, creation, and capture of value (Cozzolino et al., 2018; Teece, 2010). Thus, technologies become disruptive innovations when they are caused by changes in technology and business models to create a new value proposition for the market (Christensen, 2006; Petzold et al., 2019).

An ecosystem is an arrangement of businesses collaborating to create value jointly (Adner, 2006). Ecosystems operate through constantly evolving actors, activities and artifacts, institutions, and relationships (Beltagui et al., 2020). An innovation ecosystem is based on technology development (Ansari et al., 2016; Sandström, 2016). On the other hand, the business ecosystem represents an environment in which businesses must monitor and react (Li, 2018), to adapt to the development of emerging technologies and business ideas (Adner & Kapoor, 2010). Gomes et al. (2018) point out that innovation ecosystems are more related to value creation, while business ecosystems are more related to value capture. In this sense, in the ecosystem, a market develops around the value proposition of an innovation (Hou & Shi, 2020; Ma et al., 2018).

One of the characteristics of potentially disruptive innovations is that the value proposition of disruption can lead to the creation of new markets (Christensen et al., 2001; Nagy et al., 2016). We need to consider the disruption along with the innovation ecosystems in which they operate (Beltagui et al., 2020; Liu et al., 2020). In this way, businesses are linked to an ecology of value and must align their strategies for ecosystem success (Bers et al., 2012; Moore, 1993; Zalan & Toufaily, 2017) and the disruption within the ecosystem (Dedehayir et al., 2017). Since competition in technology-intensive industries is increasingly taking place between ecosystems (Beltagui et al., 2020; Moore, 1993), ecosystems play a crucial role in the emergence of new technology. As innovation develops in the ecosystem, companies need to find new business models to coordinate the balance between cooperation and competition and allow the creation of value for the ecosystem (Holgersson et al., 2022). In this way, the evolution of new and old technologies and the ecosystems and business models shape the technological substitution in that they are embedded (Adner & Kapoor, 2016).

2.2. Disruptive Ecosystems

Disruptive innovations are usually developed and commercialized in ecosystems and not via isolated businesses (Beltagui et al., 2020; Dedehayir et al., 2017), as the themes of disruptive innovation and innovation ecosystem intersect (Palmié et al., 2019). Business models draw the prospect of inserting disruption within the innovation ecosystem and become an important tool for the demand for the co-evolution of business strategies (Kumaraswamy et al., 2018; Rabin et al., 2020).

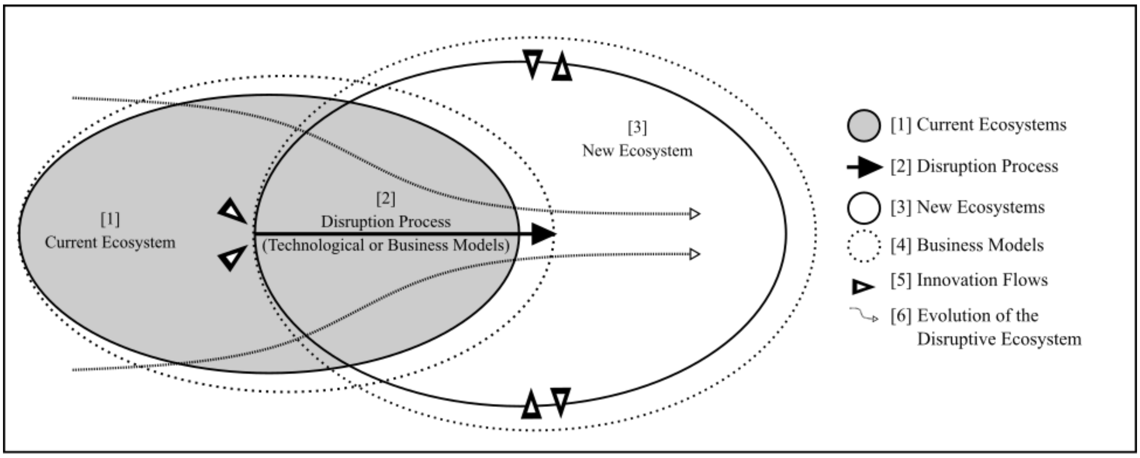
In this sense, a disruptive innovation ecosystem combines the definitions of disruptive innovations and innovation ecosystems so that an ecosystem develops and grows around an innovation (Palmié et al., 2019). Embedding a disruptive innovation in an ecosystem, complementary innovations from ecosystem members can increase the innovation's appeal and emphasize the disruption's potential to dominate the market. Here, a disruption can cause creative destruction and generate a new ecosystem based on the disruption's value proposition and business model (Clarke, 2019; Dedehayir et al., 2018). Thus, it is necessary to analyze the value generated by disruptions through a holistic perspective of the ecosystem(Adner, 2017; Jacobides et al., 2018). For disruptors, the task is to unite a new ecosystem around disruptive innovation to gain access to complementary resources from those responsible for the ecosystem they disrupt (Kumaraswamy et al., 2018).

According to the Christensen Institute (2021), three elements are necessary for disruption: the Technology, to make the product more accessible; the Business Model, to target new or marginalized consumers; and the Value Network, which targets disruption prosperity. As disruptive innovation generates great potential for change, it is usually incompatible with existing value propositions (Christensen et al., 2018; Keller & Hüsig, 2009). Thus, disruptions are innovations that can revolutionize an entire industry and substantially change its competitive patterns and value creation (Christensen et al., 2015; Kumaraswamy et al., 2018). They reconfigure strategic architectures that redefine the meaning of creating and capturing value in markets (Petzold et al., 2019; Teece, 2010). In this integration, disruptive innovation creates a demand for a new value proposition, which allows the creation of a new market (Ansari et al., 2016; Christensen et al., 2018; Kumaraswamy et al., 2018; Palmié et al., 2019; Petzold et al., 2019).

2.3. Evolution of the Disruptive Ecosystem

Silva and Grützmann (2022) present a Disruptive Ecosystem Evolution Model based on technological dynamics and innovation value, which states that disruptive innovation has the potential to transform the entire ecosystem, and it is up to the actors to co-evolve through the business models. Through the impact of **creative destruction**, disruptive innovations have the potential to transform and evolve the entire existing technological ecosystem and create new value between **incumbents** and **new entrants**. As for the ecosystem, it suffers the impact of disruption and is affected by **internal forces**, which create joint value and develop innovation within the ecosystem, and **external forces** (such as legislation, environmental pressures, social environment and supporting ecosystem) that can stop or drive disruption. Disruption business models takes the technological and strategic interdependencies between actors and become a tool for the open co-evolution of business strategies.

Figure 1 - Theoretical Evolution of the Disruptive Ecosystem Framework.



Source: Silva e Grützmann (2022).

The Disruptive Ecosystem Evolution Model (Figure 1) shows the forces that work with the impact of disruption towards the evolution of a new ecosystem. In this model, incumbents and new operators must cooperate and evolve for disruption. This process of evolution is due to the destruction of existing technologies and business models. In this process of ecosystem evolution, the idea of disruptive innovation prevails (Christensen, 1997, 2006; Christensen et al., 2018), with characteristics of old and new actors and with characteristics of old and new technologies and business models, where organizations that do not adapt to the evolving environment are disrupted and cease to exist. Hence, the model presents disruption as a tool for destroying and creating ecosystems and reconfiguring the existing value.

3. Methodology

This study aims to explore the value proposition dynamics evolution of potentially disruptive innovations in the transportation mobility ecosystem. The technological transition theory also addresses these long-term changes and is relevant to the ecosystems theory (Geels, 2002). However, this study analyses only the dynamics of the value proposition as the scope for the impact of disruption on the ecosystem.

The focus of the study was the context of new transportation mobility technologies and the latest technologies under development (EVs, AVs, and eVTOLs) as a case of ecosystem evolution. Researchers have addressed these technologies before also in the context of innovation research (Cohen et al., 2021; Cowan et al., 2014; Cugurullo et al., 2020; Fagnant & Kockelman, 2015; Rajendran & Srinivas, 2020; Wang et al., 2011).

This study chose a longitudinal exploratory case study to understand better the dynamics of the value proposition transition between ecosystem technologies (Eisenhardt, 1989;

Eisenhardt & Graebner, 2007; Yin, 1994). It is possible to use a longitudinal case study when there is a large source of data over time (Karlsson & Åhlström, 1995) to study the change of different conditions focusing on the evolution of a particular aspect (Yin, 2009). This method helps observe the emergence and stabilization of an innovation (Hargadon & Douglas, 2001) when theories do not answer the existing question and when the question relates to a process or a strategic interaction perspective that evolves (Hannah & Eisenhardt, 2018; Holgersson et al., 2018). Similar studies have been conducted in the literature to present the transition of technologies (Ansari et al., 2016; Bohnsack et al., 2021; Holgersson et al., 2018; Ozalp et al., 2018). To describe the dynamics of the value proposition between generations of transportation mobility technologies, it is important to emphasize that previous studies present past technological transitions. In contrast, this exploratory longitudinal study seeks to shed light on the technologies currently being developed in the market.

Such longitudinal studies are essential to understand the formation of generations of product and/or process innovations over long periods of time; they are an opportunity for comparative studies where generational changes tend to involve more drastic or discontinuous changes; and are helpful in managing the dynamics of technological transitions and disruptive innovations, in the sense of Schumpeterian competition, leading to changes in product generation and promoting incremental changes between these transitions; and, lastly, they focus on unique technological dynamics of disruptive innovation rather than a sequence of several innovations(Christensen et al., 2018; Holgersson et al., 2018; Ozalp et al., 2018).

3.1. Data Collection

In this study, we analyse the value proposition of the innovation ecosystem of EVs, AVs, and eVTOLs technologies under the theory of disruptive ecosystems. Factors such as actors, products, relationships, resources, activities, risks, dependencies and value created were analysed (Ansari et al., 2016; Beltagui et al., 2020; Granstrand & Holgersson, 2020; Hou & Shi, 2020). or this study, each case addresses a different technology. We followed the evolution of the value proposition within the ecosystem.

For data collection, it used secondary data sources of technologies in the market, such as reports elaborated by technology development businesses and consulting firms (Holgersson et al., 2018; Langley, 1999; Ozalp et al., 2018). In total, 25 reports of EVs, 6 of EVs and AVs, 52 of AVs, 1 of AVs and eVTOLs, and 47 of eVTOLs were collected, totaling 131 reports with 6,111 pages of documents for analysis. There sourced the list of the world's largest EV, AV, and eVTOL technology developers, as noted by Silva et al. (2023 – Article 2). Businesses' websites and the respective value statements of technology developers were analyzed to enhance the value propositions they intend to deliver to the market (Bart, 1998; Campbell, 1991; Lynn & Akgu, 2001; Raynor, 1998; Waddock & Smith, 2015). All pages were visited and collected information on 22 sites about EVs and 33 about AVs, and 10 sites with information about eVTOLs. Complementarily, for eVTOLs technology, the TNMT Innovation Hub list was also used. This data points out the leading players in the Aviation sector (6), the Automotive sector (7), the Technologies sector (5), and the leading Startups (11), and the list of the top 20 businesses in the total amount of technology patents (Lufthansa Innovation Hub, 2021). In total, the collection of information occurs on 68 websites of businesses related to the development of technologies.

Following Bohnsack et al. (2021), this study does not select scientific journals to ensure a purely narrative and non-analytical description of the analyzed data. This study analyzes 199 documents between 2009 and 2022 that contribute to developing the value proposition of technologies within the ecosystem. Combinations of these sources contributed to the data triangulation. They allowed comparing ex-post information to reduce the risk of incorrect inferences and to follow the evolution of technologies and the construction of the value proposition of technologies.

3.2. Data Analysis

The analysis started by combining data from different sources to build a comprehensive historical case for each technology (Dubois & Gadde, 2002; Eisenhardt, 1989; Holgersson et al., 2018; Ozalp et al., 2018; Yin, 1994). This study uses content analysis to build a comprehensive historical case of the value proposition of each technology in the ecosystem. As this study's scope is the dynamics of evolution, to identify and analyze changes in the value proposition of the ecosystem based on disruption, we used the Disruptive Ecosystem Evolution Model proposal to create the initial categories of the closed grid kind. We identified emerging patterns by analyzing the evolution of each technology's value proposition (Eisenhardt & Graebner, 2007; Yin, 1994). The concentration of information sought to corroborate the multiple sources of data found.

In section 4 we present a comparison between cases of the dynamic value proposition of technologies and those analyzed within the Disruptive Ecosystem Evolution Model to verify the evolutionary structure of the disruptive ecosystem. Then, in section 5, the data analysis is compared with the literature to refine the model proposal.

4. Findings

The dynamics of disruption in the innovation ecosystem affect the business ecosystem and, consequently, the business market. We recognize that the disruption will also impact the business ecosystem. As these ecosystems are interdependent, the focus is the Evolution of the Value Proposition of the Disruptive Ecosystem of Transportation Mobility Technologies in the face of a disruption which affects both the innovation ecosystem and the business ecosystem.

Our analysis begins with the presentation of the cases. Next follows the analysis of the first category of the model, Disruptive Innovation and Changing Technological Patterns, which corroborates the idea of the subtopics of Creative Destruction and Historic Operators and New Operators. The second category presents the analysis of the Innovation Ecosystem and the Driving Forces in the Internal Environment and External Environment of the Ecosystem. The third category presents the analysis of the Business Models that involve the environment and the Evolution Flows of Innovation. Finally, according to the model, we present the Evolution of the Disruptive ecosystem of transportation mobility. Even though the borders of each category overlap, we present all the categories below in isolation to facilitate the research context. The extension of the reference list is too large to present in this article, so we present a snippet of the references with numbers in parentheses, which can be seen in Appendix I.

4.1. Technology Cases

Few products have had such a profound influence on the world as transport vehicles. The automotive industry has been a force for innovation and economic growth worldwide. The combination of oil-powered ICE has dominated global transportation mobility for more than a century. That was an optimization to produce and sell ICE-based vehicles. However, since the introduction of Henry Ford's moving assembly line, changes have been both incremental and evolutionary (37; 40).

In the first decades of the 21st century, the pace of innovation is accelerating, and industry, market, resource constraints and social pressures (58; 51; 34; 57; 54) demand technological innovation with the potential to reshape the market (38). New technology with new business models different from those that currently exist could change the entire pattern of innovation and business in the existing ecosystem (25).

Introducing a more sustainable vehicle technology powered by electricity, autonomous technologies, and the possibility of air transport, for example, can trigger a disruption in the existing ecosystem (17; 34; 60; 67). EVs and AVs can change the current configuration of the transport system making it faster, more convenient, safer, more economical, sustainable and smarter.

eVTOLs allow transport even faster by airspace, with minimal infrastructure, and make it possible to fly to remote areas where there is currently no infrastructure. These technological revolutions can change how our society works, improving safety and efficiency and reducing congestion and emissions (51; 26; 59; 8; 54; 46; 9).

The transportation mobility market tends to be driven by electric, autonomous, intelligent, connected, and airspace exploration technologies (Advanced Air Mobility - AAM). We are currently in the early stages of a potentially disruptive evolution. These new technologies are mainly products based on new hardware and software systems (12; 56; 57; 43). Established players and new entrants are working to develop this new transport reality (46; 42; 25).

Technology will play a vital role in the evolution of this ecosystem, and the pace of innovation is accelerating (17). Rather than a technological monolith, these new technologies will coexist, and innovation will continue on multiple fronts, building a blended technological ecosystem within the market (40; 16; 20). A broad and rapid reorganization of these ecosystems in the face of these potential disruptions could have far-reaching consequences for the entire market value proposition. The following sections present the impact of disruption and the change in the value proposition in the ecosystem according to the Disruptive Ecosystem Evolution model.

4.2. Disruptive Innovation and Changing Technological Patterns

Disruptive innovation has the potential to transform the entire ecosystem, as EVs, AVs, and eVTOLs technologies have the potential to have the disruptive effect of transforming or evolving the ecosystem. EVs are emerging, with various players within the auto industry developing electromobility technology. In the process of EV disruption, there will be various hybrid combinations to meet market needs until complete disruption happens (40). Strategies will require rebuilding technological resources to catch up with the dominant players' operations and manufacturing levels. The Renault-Nissan-Mitsubishi alliance is a sign of this restructuring of the EV market (59; 51). Disruption occurs in the electric motor world, where ICEs cease to exist. The transition to EVs will occur gradually as it significantly impacts the current value structures of all ecosystem actors (25; 15).

AVs combine artificial intelligence, user-centered design, connectivity, and sophisticated manufacturing (43; 9; 30). This transformation will occur with the evolution of EV companies and technologies and by new technological and software players. Orange, IBM, Google, and Amazon are companies that participate in building this connectivity through artificial intelligence as a key factor in AVs (52; 31). is transformation is changing the automotive industry's value chain and creating an intelligence-based ecosystem. Automation technology will power on-demand mobility as a service (MaaS) and could disrupt the market (56; 12). In the long term, the evolution of these advances will cause a rebalancing of the value chain, with non-traditional companies playing a more significant role.

On the other hand, the eVTOLs disruptive process demands a high intensity of technological development, which can even create a new segment of commercial mobility (46; 65). In this evolving ecosystem, the opportunities are relevant for all players, but the risks seem more significant for aerospace companies that may experience disruption. Companies such as Bell, Leonardo, and Honeywell are developing the technology to actively participate in disruption (12; 13: 14; 21; 4; 44; 29). Although current operators may risk suppression by the new ecosystem of eVTOLs, the AAM will not replace the existing mobility system but will integrate it as a complementary element to the future mobility ecosystem (60; 20; 46). The main disruption factor is anchored in the collaboration of different actors for the evolution of the ecosystem and the creation of a new segment of commercial mobility in the market.

4.2.1. Creative Destruction

Creative destruction occurs when new technologies allow new and better products to displace the dominant products in the market. The effect of creative destruction occurs even more quickly due to the potential disruption of the three technologies addressed in this study. Manufacturing is no longer the core competency, which explains new entrants as part of the disruption. Software-defined vehicles replace the traditional lifecycle, value chain, and especially the value proposition of the mobility ecosystem that is being redefined based on electrification, automation, connectivity, and aerial technologies (43; 13: 14; 25; 47; 54).

Within the business ecosystem, vehicle assembly companies are increasingly focusing on manufacturing EVs (51; 59; 26; 64). There are partnering with companies and startups for investments in automation and connectivity technologies. Companies such as Google, Intel, Tencent, Aurora, Cruise, and Uber (37; 12; 48), and in air forms of transport such as Embraer, Joby Aviation, and Lilium (18; 35; 45), are signals that the destruction of the existing pattern is already taking place. This strong demand (and supply) from the ecosystem and new disruptors have leveraged the development of new technological standards.

4.2.2. Historical and New Operators

The change in the value chain, integrating new actors into the existing ecosystem, can be a source of competitive advantage to face disruption. Actors make the EV ecosystem from within the auto industry itself: the Renault-Nissan-Mitsubishi alliance and the partnership between Honda and General Motors are examples of partnerships and collaborations to develop and explore the market (28; 59; 51). Evolving EV companies and adding new entrants from the software technology industry make the AV ecosystem. Traditional car manufacturers such as Toyota, Nissan, and Fiat have decades of experience designing and manufacturing vehicles and are currently adapting to the demand for EV manufacturing (64; 51; 26). Meanwhile, the disruption of AVs by new entrants such as Tesla and Uber, incumbents of technology such as Google/Waymo and IBM have developed the technologies needed to automate and connect vehicles (62; 66; 2; 32).

The new eVTOLs ecosystem is even broader, with manufacturers from the automotive sectors like Honda, Hyundai, and Porsche, aerospace like Airbus and Boeing, ride-sharing companies like Uber, broader transport companies like Toyota or JetBlue and retailers like Amazon, and startups like Volocopter, Skydrive and Terrafugia operating in this space (28; 30; 53; 1; 7; 66; 49; 46). Startups are dominating the eVTOL innovation ecosystem, partly because they have market-critical technology and partly because they have higher risk tolerance. What remains common to the disruption of EVs, AVs, and eVTOLs technologies are the relationships created between the different historical and new actors in developing the new ecosystem.

4.3. Innovation Ecosystem

Ecosystems are networks of interconnected and interdependent businesses to develop technologies. The EV ecosystem is evolving in a market with many experienced ICE players. This disruption occurs due to a substitution in the technological standard, which affects all actors in the value chain (25). Some ICE manufacturing companies have chosen to leverage their own technologies in isolation, such as Toyota and BMW, while others, such as Fiat, Chrysler, and Nissan, have chosen to form partnerships to develop the technological ecosystem (64; 6; 26; 51). In turn, AVs take advantage of the EV ecosystem to evolve alongside new companies in automation technologies, connectivity, the internet of things, artificial intelligence, cloud computing, and big data, among others (43; 43; 67). Cooperation has become key to developing automation technology and accelerating the ecosystem.

The eVTOL ecosystem encompasses the activities of its wide range of participants (see topic 5.1.2) as they collaborate to develop the various necessary technologies. Partnerships became the foundation for success in this new and complex AAM space. Joby Aviation has partnerships with Hyundai and Toyota, in addition to having acquired Uber Elevate, Google has acquired Kittyhawk, and several other companies and startups are seeking partnerships (35;

36). This approach promotes shared ideas and nurtures new opportunities for research, technology development, infrastructure, management, and market exploration (46; 63; 44).

The competitive landscape of these new mobility industries is constantly changing. Cooperation is a prerequisite in all areas of the ecosystem to mitigate complex challenges. The wide range of skills and capabilities needed to develop the technologies is almost nonexistent in a single player (12). Software competence is becoming one of the most critical differentiators for the industry (43; 46; 47). In addition to the lack of technological or process knowledge, there are other reasons to join forces, such as reduced development costs, reduced technological innovation cycles, greater competitiveness, more significant influence in defining standards of autonomous driving systems, and risk sharing (60; 43). In this more complex and diverse scenario, established players will force competition simultaneously on multiple fronts and cooperate with competitors.

4.3.1. Driving Forces: Internal and External Environment of the Ecosystem

The ecosystem unification depends upon the forces that drive the necessary change. As a technology with the potential to create disruption in the existing ecosystem, EVs, AVs, and eVTOLs experience forces that can block or drive the disruptive potential.

- The role of the government's **Policy and Regulation** is necessary so that tax benefits and government incentives can release and expand the development of technologies and the market itself (34; 40; 24; 60; 47).
- **Environmental Pressures** for a global climate agenda is another relevant factor. New technologies can reduce fossil fuel consumption and greenhouse gases and are viable solutions to the current model based on ECIs (58; 51; 34; 57; 54).
- In **Social Environment** the public perception of benefits (such as cost reduction, reduction of road maintenance costs, reduction of accidents, reduction of traffic jams, increase in speed and economy, gain in travel time and the new safe experience of MaaS on-demand) are positive factors that can drive technology acceptance and market development (60; 27; 46; 22).
- The **Technological Support Environment** is necessary to support nascent technologies' development. Smart vehicles need smart infrastructure for vehicle-to-vehicle communications. The technological maturity of components (such as batteries and software are necessary, as well as the 5G technology infrastructure for intelligent communication between vehicles, the charging infrastructure for EVs and AVs, and the eVTOLs take-off and landing points adopted in cities, the network of providers of services, among others) are necessary to support the nascent technology and reach market diffusion (40; 43; 60; 39; 41; 23; 33; 55; 13; 50).

New technologies are still in their early stages in many emerging markets and developing economies. Working with technology that did not exist before implies an infrastructure that does not exist yet, and requires new regulations. New technologies offer countries and regions a variety of opportunities to exceed carbon transport standards, boost economic efficiency, and circumvent or alleviate negative impacts such as air pollution and congestion. Failure to properly develop the technologies and ecosystem can create bottlenecks. However, the correct investment in the ecosystem and the future market can expand the development and growth of the technology.

4.4. Business Models

Business models are a set of procedures and principles of value creation and can be very distinct between companies. As previously shown, some companies such as Tesla, Toyota, and BMW chose to develop technologies in isolation in search of competitive advantage. In contrast, other companies chose to carry out partnerships, mergers, and/or acquisitions to develop the EV ecosystem. Many vendors seek to combine components to facilitate the vehicle integration ecosystem (25; 11; 43). This adaptability of technologies seeks to make vehicle manufacturing more flexible and dynamic. This causes most major industry players to collaborate across the value chain to leverage partners' technology capabilities (25). These strategies will shape the transformations and generate a competitive advantage for the ecosystem against competitors.

There is no clear leader in the AV ecosystem in developing this technology, and no dominant design exists. Some technologies are used on all fronts, but a clear path to automation still needs to be defined (43). Companies are collaborating to develop technology while competing to get market share. There is a combination of the experience of incumbents in designing and manufacturing vehicles with the ability of technology companies and startups to develop the necessary software. Cooperation between various parties is forming new industrial chains for AV development (58; 59; 2; 66). Several partnership strategies seek to fill the skills or technology gaps needed to accelerate the development of AVs and remain competitive in this evolution.

The dynamic evolution of eVTOLs is even greater. Incumbent operators from various markets and startups to develop technologies for exploring the future market. Startups are created exclusively to develop and exploit this technology, are at the forefront of technology and have greater flexibility to adapt to changes in the market (64; 30, 35; 45; 68; 4; 44). Large-scale incumbents actively participate in market development but hold out for the market to mature first. Thus, incumbents can ally with startups to mitigate risks (46; 13). The collaboration of all these members aims to share problems and answers and develop a dominant technology design, seeking a share of this new market.

Business models are the most apparent difference in the three technologies business ecosystem. While EVs tend to continue the vehicle acquisition model adopted in ICEs, AVs, and eVTOLs are mostly on-demand MaaS (38; 40; 43; 47; 51; 26; 61). The eVTOLs are responsible for medium-distance trips and the AVs for short distances, such as the first and last miles (66; 17). Disruption of EVs, therefore, occurs in the value chain of the technology innovation and production ecosystem. However, the disruption brought by AVs and eVTOLs happens as much in the innovation ecosystem value chain as it does in the market and business ecosystem.

4.4.1. Innovation Flows

Disruption can benefit members of the ecosystem-built coopetitive processes through flexible and open Innovation processes. In the case of EVs, some companies have chosen to maintain a closed innovation flow, focusing on internal competencies to generate unique value in the development and exploration of the market. The clearest example is Tesla, which committed to vertical integration, manufacturing everything from its production equipment to a charging station network (62; 40). On the other hand, other companies opted for a more open flow of innovation, as is the case of the Renault-Nissan-Mitsubishi alliance and Fiat Chrysler (59; 51; 26) for the development of the market's technology and business ecosystem.

In the case of AVs and eVTOLs, open innovation flows predominate. Different technologies are necessary for developing these markets: experience and manufacturing capacity, batteries, sensors, propulsion, automation software development, connectivity, 5G, the internet of things, artificial intelligence, cloud computing, big data, among others. The partnership between BMW, Mobileye and Intel aims at developing automation technologies (43; 31; 32; 9; 52; 46; 13; 10; 5). In this model, companies open up to a diverse group of external players (partners, suppliers, competitors, startups, universities, among others) in several countries and with very different realities, which promotes an ecosystem of creativity for the development of new technological solutions. Open Innovation drives growth through an innovative collaboration between all parties. This diverse innovation ecosystem can leverage the best of all actors to build disruption within the ecosystem itself.

4.5. Evolution of the Disruptive Transportation Mobility Ecosystem

In this process of Evolution of the Disruptive Ecosystem, the ecosystem must evolve into a new ecosystem through disruptive Innovation. Research data points to companies belonging to the ICE ecosystem as the basis for the evolution of the EV ecosystem (11; 43). The process started based on a disruptor actor, but almost all actors responsible for manufacturing, suppliers, and infrastructure, among others, were part of the composition of the newly evolved ecosystem. Another part was made by new entrants who challenged the status quo of technology and dominant companies. As part of the disruption principle, companies that did not follow such evolution of the disruptive process tended to disappear from the ecosystem. The business ecosystem value proposition was applied based on the advantages of the new technology, mainly concerning the sustainable gains of EVs. For the innovation ecosystem, the value proposition changed entirely based on the new value chain produced by electromobility technology.

AV technology was built on the electromobility ecosystem created by EVs. With disruptive automation and connectivity technology created by new entrants, incumbents, and startups from the software and internet sector, it was possible to evolve into the new transportation mobility ecosystem (43; 43; 67). Although there is no clear leader, the collaboration between the companies was a fundamental factor in developing the technology. In this impact, the value proposition of the business ecosystem would be most strongly affected by factors such as travel security, reduced ownership costs, and especially by offering MaaS on-demand (43; 51). On the other hand, the value proposition of the innovation ecosystem changes with the insertion of new entrants with the disruptive technology of automation and connectivity. The vehicle's manufacturing capacity ceased to be the main factor within the ecosystem and became the production of automation technology. The entire ecosystem was changed based on the new disruptive technology. A new ecosystem was created based on the existing mobility companies and the new entrants in the technology sector.

Lastly, in a similar fashion, the ICE ecosystem evolved into the EV ecosystem, and this one which, with the participation of new entrants from the technology sector, also evolved into the AV ecosystem, may evolve into the eVTOL ecosystem. The most important factor is that the eVTOL ecosystem is made up of companies from the automobility and aeromobility sectors, but the essential technology for the development of this ecosystem comes from the technology and software sector, which already participated in the previous AV ecosystem (28; 30; 53; 1; 7; 66; 49; 46). Startups play a crucial role in developing this ecosystem, as they can take risks that large companies cannot. The most critical tool in developing this ecosystem is the collaboration of the various actors (35; 19; 68; 36; 3).

For the various sectors that invest in eVTOL technology, the value proposition of the business ecosystem is the possibility of evolving their own businesses, be it transport, logistics, retail, or military, among others, or of capturing a slice of the new and immense market that is about to open. As for the innovation ecosystem, the value proposition was the total change of the ecosystem. It was composed of different sectors of manufacturing technology, in particular automotive and aerospace, but in which the software and connectivity technology sector became a priority. Prototypes of flying vehicles have existed but have never been commercially produced. The project was only possible thanks to the development of electric battery technologies for EVs and automation for AVs. This enables the evolution of innovation ecosystems based on the disruptions that affect them.

5. Discussions

This study aims to present the evolution of EVs, AVs and eVTOLs as technologies with the potential to change the technological and value standard of the current transportation mobility market. As this is an evolving ecosystem, it is composed of different actors who participated in the initial ecosystem and new entrants who adapted to the development of the disruption and developed the new disruptive ecosystem. This proposal remains in line with the theory that points out that disruptions have the potential to create value based on the disruption changing the entire ecosystem (Adner, 2006; Granstrand & Holgersson, 2020; Holgersson et al., 2022; Palmié et al., 2019; Yaghmaie & Vanhaverbeke, 2019), even creating new markets (Christensen et al., 2018; Cohen et al., 2021; Kumaraswamy et al., 2018; Nagy et al., 2016; Silva & Grützmann, 2022).

Our results point out that the transformation of the intelligence-based mobility market is changing the entire value chain and proposition, where manufacturing is no longer a core competency of the transportation mobility industry. The research results also point to the entry of actors from different sectors to the development of a new technology, which hints towards a disruptive process in the ecosystem. These findings corroborate studies that indicate that the value proposition is central to ecosystem transformation (Dedehayir et al., 2018; Oghazi et al., 2022; Palmié et al., 2019; Tsujimoto et al., 2018) and that technologies and actors can be the start of disruption in the ecosystem (Ansari et al., 2016; Nagy et al., 2016; Ozalp et al., 2018).

The research also points out that EV, AV, and eVTOL technologies are becoming part of an evolutionary process, creating value within the perspective of technological development (Innovation Ecosystem) and will be complementary within the market value capture perspective

(Business Ecosystem). These findings corroborate previous research on creating and capturing ecosystem value (Gomes et al., 2018; Granstrand & Holgersson, 2020; Gu et al., 2021; Pushpananthan & Elmquist, 2022; Tsujimoto et al., 2018). Also corroborating the existing literature (Clarke, 2019; Dedehayir et al., 2017; Sandström, 2016), our results point out that both ecosystems are part of the process of creative destruction within the existing ecosystem and create a new disruptive ecosystem with a new value offer.

The research results also highlight that in this new ecosystem, actors seek the necessary resources (technical and non-technical) to integrate them into the ecosystem's various business models and be well-positioned for the future. The opening of the ecosystem's disruptive process promotes collaboration between actors from different technological sectors for the development of EVs, AVs, and eVTOLs technologies. Collaboration is already taking place across the ecosystem, and various actors are working to develop this universe utterly different from the current mobility industry. These findings support the innovation ecosystem theory, where the ecosystem creates value through collaboration and long-term benefits for all those involved in the ecosystem's future (Adner, 2006; Ansari et al., 2016; Beltagui et al., 2020; Sandström, 2016). Our findings also validate the literature (Adner & Kapoor, 2010; Bers et al., 2012) where the ecology of actors' value is linked to the success of the ecosystem. A development cycle dictates the uneven evolution of technology in the face of ecosystem participants.

As for the business ecosystem, our results show that the forces that drive technology and time will be critical factors for the technologies' success. The shift to new technologies will not likely be linear, as incumbents need to sustain their core businesses. This will require a balance between business first-movers, demand from the driving forces of new technologies, and technology substitution advantages. A mixed landscape of the evolution of the business ecosystem will occur, with different technologies cohabiting the transportation mobility ecosystem until the new technologies mature and surpass the existing ICEs. These results are in line with the theory regarding the evolution of ecosystems (Adner & Kapoor, 2016; Beltagui et al., 2020; Pushpananthan & Elmquist, 2022; Silva & Grützmann, 2022), and will allow old and new operators to gain space if they adapt to the new ecosystem in disruption.

According to the Disruptive Ecosystem Evolution Model proposal, the ecosystem innovation flow between collaborating actors aims to develop disruption within the new ecosystem. An evolutionary adaptation occurs, generating disruptive changes in the ecosystem. Unlike radical innovation that destroys the ecosystem pattern, disruptive innovation will generate evolution and adaptation along with the ecosystem. To this end, we propose the concept of a “Dynamic Value Proposition” that accompanies the impact of disruption and adaptively evolves the value proposition along with the ecosystem. Thus, this dynamic of evolution and adaptation of the value proposition of the disruptive ecosystem of EVs, AVs and eVTOLs constitutes the new Transportation Mobility Value Ecosystem. These findings align with the disruptive ecosystem's theoretical proposal in which the entire ecosystem adapts to disruptive change (Christensen et al., 2018; Cohen et al., 2021; Dedehayir et al., 2017; Palmié et al., 2019; Silva & Grützmann, 2022).

5.1. Theoretical Contributions

This study presents essential contributions to the literature. First, it contributes to expanding knowledge about the impact of a disruption on an innovation ecosystem (Christensen et al., 2018; Kumaraswamy et al., 2018; Palmié et al., 2019). Disruption can generate waves of evolution and adaptation of the actors, creating a new ecosystem based on disruptive technology and based on the different actors that enter the ecosystem. Likewise, this study also contributes to the innovation ecosystem value proposition literature (Christensen, 2006; Christensen et al., 2018; Dedehayir et al., 2017; Jacobides et al., 2018). As a clearer picture of the impact of disruptive innovation on this initial value proposition, our study shows that when the disruption impacts the ecosystem, it changes its value proposition to adapt to the disruptive process. To this end, innovation ecosystems undergo an adaptation of the value proposition, creating a new ecosystem with characteristics of the new technology and the different actors that coexist and collaborate.

This study also contributes to the business ecosystem literature (Adner & Lieberman, 2021; Christensen et al., 2018) by expanding the knowledge of new technologies and their impact on the market. When under the effect of a disruption, the ecosystem seeks to adapt to the disruptor and the disruptive effect, creating a space for developing new technology. In this case, incumbent operators and new entrants can add value while remaining within the evolutionary strategy of disruption within the ecosystem.

The applications of the Disruptive Ecosystem Evolution Model should be considered. This model, initially developed to represent the impact of a disruption in the ecosystem, proved to be a valuable tool for discussing the evolution of the ecosystem's value proposition in the face of disruptions. In addition to the results of this study confirm the evolution model of the disruptive ecosystem, it was also possible to present the evolution of the value proposition based on the technological transition. This study also contributes to creating the Dynamic Value Proposition concept, which adapts and evolves along with the disruptive ecosystem.

5.2. Practical and Managerial Contributions

For practice, this study contributes to understanding the impact that new technologies of EVs, AVs, and eVTOLs can have on current transportation mobility. Companies must prepare for the impact of disruption on different actors and the possible creative destruction of the ecosystem. Understanding the driving forces needed to pave the way for disruption and the business models to leverage this tangle of ecosystem actors is necessary. In the case of the evolution of the transportation mobility market, managers need to prepare for the process of adapting to disruption.

This study also contributes to understanding the impact of EVs, AVs, and eVTOLs technologies on the market value proposition. Value chains are changing, new and different actors are contributing to the growth of technologies, and new actors will appear to use the business ecosystem. Since the joint effort to develop these technologies is broad and covers several technology fields, managers must prepare for the market disruption's effect and the new opportunities that will appear.

6. Conclusions

This study aimed to explore the value proposition dynamics evolution of potentially disruptive innovations in the transportation mobility ecosystem. To this end, a longitudinal study of the Disruptive Ecosystem Evolution Model was carried out to understand the dynamics of transition and adaptation of the value proposition of new transportation mobility technologies. In the proposed model, it was possible to understand the evolution of ecosystems based on the disruption of EVs, AVs, and eVTOLs technologies.

In light of the evolution and adaptation of the disruptive ecosystem, the entry of new technologies and companies in the transportation mobility ecosystem impacts incumbent operators and new entrants. This impact of technology on actors due to disruption generates a process for adapting to the new ecosystem (Dedehayir et al., 2017; Palmié et al., 2019; Silva & Grützmann, 2022). Actors who do not adapt to the process may be left out of the ecosystem (Christensen et al., 2018). Disruptive innovation will thus direct the ecosystem's future, in the form of a mosaic, with part of the historical and current capabilities within that ecosystem.

The Evolution Dynamics of the Value Proposition show the makeup of a new ecosystem based on the capabilities of the initial ecosystem. Until disruption occurs, a mosaic of technology development predominates with features from the dominant incumbents of the ICE ecosystem evolving into EVs and the new entrants of AVs, and eVTOLs. Faced with the impact of disruption, collaboration is a fundamental factor for the dynamics of adaptation of the value proposition and the evolution of new ecosystems. Based on the disruptive impact of EVs, AVs, and eVTOLs, the dynamic value proposition is part of the evolution of technologies and the transportation mobility ecosystem.

6.1. Limitations and Suggestions for Future Research

This study has a few limitations: first, it was limited to using a single model to discuss the transition of the value proposition of technologies. Based on the research of the Disruptive Ecosystem Evolution Model, we suggest further studies to understand the dynamic effect of the ecosystem value proposition during a disruptive process. As the value proposition of transportation mobility technologies is continuously changing, there is a need to expand research in this area, which is why we also recommend researching future scenarios related to developing these new technologies. It is also suggested to use the value proposition transition research in other sectors to validate the Disruptive Ecosystem Evolution Model. This study was also limited by design to the exclusive use of industry reports and websites for development – we suggest using other sources such as scientific articles, patents, interviews, podcasts and even companies' social networks for data collection and triangulation.

Appendix I

№	Source	№	Source
1	Airbus, 2022 (Official Website)	35	Joby Aviation, 2022 (Official Website)
2	Alphabet/Google, 2022 (Official Website)	36	KittyHawk, 2022 (Official Website)
3	Autoflight Global, 2022 (Official Website)	37	KMPG, 2012 (Report: Self-driving cars- The next Revolution)
4	Bell, 2022 (Official Website)	38	KPMG, 2018 (Report: Autonomous Vehicle Readiness Index)
5	BMW, 2017 (Report: In Sprints towards Autonomous Driving)	39	KPMG, 2020 (Report: Shifting gears- the evolving electric vehicle landscape in India)
6	BMW, 2022 (Official Website)	40	KPMG, 2021 (Report: Place your billion-dollar bets wisely)
7	Boeing, 2022 (Official Website)	41	KPMG, 2022 (Report: Electric vehicle charging – the next big opportunity)
8	Catapult, 2019 (Report: Market Forecast For Connected and Autonomous Vehicles)	42	KPMG, 2022 (Report: Elevate Perspectives)
9	Daimler, 2022 (Official Website)	43	KPMG, 2022 (Report: Levelling Up China's race to an autonomous future)
10	Dell, 2021 (Report: A Complete, Open and Hybrid Approach to Autonomous Vehicle Development)	44	Leonardo, 2022 (Official Website)
11	Deloitte, 2017 (Report: Framing the future of Mobility)	45	Lilium, 2022 (Official Website)
12	Deloitte, 2019 (Report: Autonomous Driving Moonshot Project with Quantum Leap from Hardware to Software & AI Focus)	46	Lufthansa, 2021 (Report: Are Air Taxis Ready For Prime Time?)
13	Deloitte, 2019 (Report: Change is in the air The elevated future of Mobility)	47	McKinsey, 2016 (Report: Automotive revolution – perspective towards 2030)
14	Deloitte, 2019 (Report: Change is in the air The elevated future of mobility: What's next on the horizon?)	48	McKinsey, 2016 (Report: Automotive Revolution)
15	Deloitte, 2022 (Report: Electric vehicles Setting a course for 2030)	49	NASA, 2021 (Official Website)
16	Dunsky, 2019 (Report: City of Toronto Electric Vehicle Strategy)	50	NHTSA - Federal Automated Vehicles Policy, 2016 (Report: Accelerating the Next Revolution In Roadway Safety)
17	Embraer X, 2020 (Report: Flight Plan 2030)	51	Nissan Motor, 2022 (Official Website)
18	Embraer, 2022 (Official Website)	52	Orange, 2022 (Official Website)
19	EVE, 2022 (Official Website)	53	Porsche, 2022 (Official Website)
20	Evtol Insights, 2020 (Podcast: Ep. 1 - Lilium's Oliver Walker-Jones, head of communications)	54	PWC, 2018 (Report: Five trends transforming the automotive industry)
21	Evtol Insights, 2020 (Podcast: Ep. 27 - Adam Cohen of UC Berkeley, California)	55	PWC, 2018 (Report: Industrial Mobility and Manufacturing)
22	Evtol Insights, 2020 (Podcast: Ep. 31 - Yolanka Wulff, Co-Executive Director of the Community Air Mobility Initiative (CAMI))	56	PWC, 2020 (Report: Digital Auto Report- Navigating through a post-pandemic world - Volume 1)
23	EY, 2022 (Report: Mobility Consumer Index Study)	57	PWC, 2021 (Report: Digital Automotive Report- Accelerating towards the new normal)
24	EY, 2022 (Report: Power sector accelerating e-mobility)	58	PWC, 2021 (Report: E-mobility in India)
25	EY, 2022 (Report: Unlocking the Electric Mobility Value Pools)	59	Renault, 2022 (Official Website)
26	Fiat Chrysler Automobiles, 2022 (Official Website)	60	Roland Berger, 2018 (Report: Urban air mobility - The rise of a new mode of Transportation)
27	Fukushima, 2019 (Report: Headed towards "Air Mobility Revolution")	61	Rolls-Royce Holdings, 2022 (Official Website)
28	Honda, 2022 (Official Website)	62	Tesla, 2022 (Official Website)
29	Honeywell, 2022 (Official Website)	63	The Business Research Company, 2022 (Report: eVTOL Aircraft Global Market Report)
30	Hyundai, 2022 (Official Website)	64	Toyota, 2022 (Official Website)
31	IBM, 2021 (Report: Automotive 2030 Racing toward a digital future)	65	Uber Elevate, 2016 (Report: Fast-Forwarding to a Future of On-Demand Urban Air Transportation)
32	IBM, 2022 (Official Website)	66	Uber, 2022 (Official Website)
33	ICCT, 2018 (Report: The continued transition to Electric Vehicles in US Cities)	67	Volkswagen, 2022 (Official Website)
34	IEA, 2022 (Report: Global Electric Vehicle Outlook 2022)	68	Volocopter, 2022 (Official Website)

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ARTICLE 5 – THE EVOLUTION OF THE DISRUPTIVE ECOSYSTEM: A SCENARIO PROPOSITION FOR THE DISRUPTION OF EVTOLS TECHNOLOGY AND THE ADVANCED AIR MOBILITY ECOSYSTEM

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People still cling to this belief that innovation is just random and unpredictable. But if you look closely, there are some real patterns. The companies that recognize and take advantage of those patterns have the real opportunity to create competitive advantage.
(Clayton M. Christensen)

THE EVOLUTION OF THE DISRUPTIVE ECOSYSTEM: A SCENARIO PROPOSITION FOR THE DISRUPTION OF EVTOLS TECHNOLOGY AND THE ADVANCED AIR MOBILITY ECOSYSTEM

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Abstract

Purpose: To identify and to analyze the possible scenarios for the potentially disruptive innovations of eVTOLs and the Advanced Air Mobility (AAM) ecosystem.

Design/methodology/approach: We apply content analysis to the various official documents of eVTOL technology companies and apply it based on the constructs of the Disruptive Ecosystem Model to build the case study of eVTOLs and AAM.

Findings: The main results point to the collaboration of actors from different sectors to develop the technology. The results also point to the co-evolutionary process of strategies between actors, technologies, and business models of the disruptive ecosystem.

Originality: This is one of the first studies to present the potential of the disruptive ecosystem of eVTOLs and the AAM market.

Research limitations/implications: This study was limited to secondary data and analysis within the proposed model. This study contributes to disruptions and ecosystems theories by conducting an ex-ante study of the insertion of disruptive technology in the market. This study also contributes by presenting the proposal for an innovation biome, or disruptive biome, which is aligned with the evolutionary process of the multiple ecosystems that are part of the core disruptive technology.

Practical/managerial implications: This study contributed in a practical and managerial way by pointing to the development of disruptive innovation of eVTOLs within the new AAM ecosystem and market. This article also contributes to developing possible strategies for implementing technologies and innovations within the ecosystem.

Keywords: Disruptive Innovation; Innovation Ecosystem; Disruptive Ecosystem; Business Models; eVTOLs.

1. Introduction

Technological change is perhaps the most powerful driver of market development. Currently, it cannot know from which direction a disruptive innovation will come, although the market shows readiness for future disruptive innovations (Klenner et al., 2013). Recent studies point out how an increasing number of disruptions have the potential to reshape the way companies and industries operate (Christensen et al., 2018; Kumaraswamy et al., 2018). Because these disruptions are not easily accessed or copied (Mukhopadhyay & Whalley, 2021), disruptions become ongoing challenges that shake many industries and ecosystems and can lead to the opening of new markets

(Palmié et al., 2019). In this way, disruptions are not developed and marketed by isolated companies but by ecosystems (Ansari et al., 2016; Kumaraswamy et al., 2018).

Studies indicate that the occurrence of disruption can transform the entire structure of an ecosystem (Christensen et al., 2018; Kumaraswamy et al., 2018; Palmié et al., 2019). Several examples of disruption in ecosystems can be cited: the TiVo technology in the television market (Ansari et al., 2016); Netflix's video-on-demand technology in the film industry (Salvador et al., 2019); Airbnb's business model in the hotel market (Tham, 2016); open education models compared to the traditional education system (Rabin et al., 2020); or the new technologies of fintechs compared to traditional banking institutions (Lee & Shin, 2018; Palmié et al., 2019; Zalan & Toufaily, 2017). We learn from these cases that ecosystems are rarely stable since the forces (technology) that affect their structure, over time, cause the dynamics of evolution (Holgersson et al., 2022). However, new studies need to understand the creation, evolution and replacement of current standards by new technologies (Gu et al., 2021).

Academic literature still needs to provide a clear picture of the impact of disruptive innovation on the ecosystem. The literature only explores how existing ecosystems are affected by disruptive innovations (Ansari et al., 2016; Oghazi et al., 2022; Ozalp et al., 2018). This gap is related to the fact that disruption actors can impact the ecosystem, reconfiguring the disruption value model and resulting in the creation of a new ecosystem (Ansari et al., 2016; Dedehayir et al., 2017; Ozalp et al., 2018; Palmié et al., 2019; Silva & Grützmann, 2022). Therefore, it becomes necessary to understand the evolution of ecosystems, considering the potential of disruptive innovations (Christensen et al., 2015; Oghazi et al., 2022; Palmié et al., 2019; Silva & Grützmann, 2022).

The gap in the evolution of ecosystems becomes more evident as investigations focus on the ex-post effect of innovation (Chen et al., 2016). Although some more recent studies have focused on the antecedents of ecosystem evolution ex-ante (see Blume et al., 2020; Chen et al., 2016; Govindarajan & Kopalle, 2006; Keller & Hüsig, 2009; Klenner et al., 2013; Müller & Kunderer, 2019; Schoemaker & Mavaddat, 2000; Sood & Tellis, 2011), there seem to be inconsistencies in this theme, especially concerning the transition of the technological standard, ecosystem value proposition, market logic and evolutionary elements based on disruption (Oghazi et al., 2022). Following this example, Silva e Grützmann (2022) present a Disruptive Ecosystem Evolution Model that considers the transition model of disruptive technology in an existing ecosystem and proposes an evolution process for a new ecosystem. Therefore, investigating where and how ecosystem evolution occurs helps to interpret and analyze how disruptive innovation affects industries and triggers new business models and innovation ecosystems (Dedehayir et al., 2017; Palmié et al., 2019).

Such a gap was also not researched in the transportation mobility sector. In this sense, the transportation mobility industry has suffered a great impact in the insertion of the most recent technologies. The current market standard centered on the technology of internal combustion engines (ICE) suffer the impact of the insertion of new electrification technologies (Electric Vehicles - EVs) and vehicle automation (Autonomous Vehicles - AVs). In their infancy, electric vertical take-off and landing vehicles (eVTOL) bring a new perspective to Advanced Air Mobility (AAM), where Urban air mobility (UAM) is a subset of AAM, and contemplate possibilities for market Development (this article will refer to AAM to booth concepts) (Cohen et al., 2021; NASA, 2020; Reich et al., 2021; US Department of Transportation, 2022). Faced with the impact of a potential disruption represented by the new technology of eVTOLs, it is important to design the possible scenarios in which innovation can disrupt the ecosystem (Blume et al., 2020; Christensen, 2006; Christensen et al., 2018; Kumaraswamy et al., 2018; Lavikka et al., 2018; Schoemaker & Mavaddat, 2000). Specifically, in this study, the current transportation mobility ecosystem.

Based on the identified gaps and an exploratory approach, this study asks what are the possible scenarios for the potential disruption of eVTOLs and the Urban Air Mobility Ecosystem? In this way, the research aims to identify and to analyze the possible scenarios for the potentially disruptive innovations of eVTOLs and the Advanced Air Mobility ecosystem. This study proposes to use the Disruptive Ecosystem Evolution Model to carry out an exploratory study with a predictive purpose to explore the insertion of a potentially disruptive technology of eVTOLs in the existing transportation mobility ecosystem.

Assuming that disruption occurs as a process over time, the occurrence of disruption may only be evident after introducing the innovation to the market. This makes it challenging to collect data on disruptive innovations within an analysis period in an innovation survey (Christensen, 1997; Christensen et al., 2018; OECD, 2018). Therefore, due to a lack of defined frameworks for identifying the insertion of disruptive innovations, we applied the Disruptive Ecosystem Evolution Model to perform an ex-ante analysis of the disruptive potential of eVTOLs.

This study contributes to the theory of disruptions and ecosystems by using it to perform a study to perform the insertion of a disruptive technology ex-ante of market insertion. It also contributes by applying an ex-ante analysis method with current data on a potential technological change in the real market and providing insights into the impact of a potential disruption on the ecosystem. In this way, the knowledge generated, in a managerial way, provides direction for developing technology within the new ecosystem and the market.

Therefore, this article can be seen through the logic of developing strategies for implementing technologies and innovations within the ecosystem.

2. Theoretical Background

2.1. Disruptive Innovation and Innovation Ecosystems

The theory of disruptive technologies explores how innovations with different characteristics have come to outperform dominant technologies in the market (Bower & Christensen, 1995; Christensen, 1997; Christensen et al., 2018). These technologies become disruptive innovations caused by changes in technology and business models to create a new value proposition for the market (Christensen, 2006; Petzold et al., 2019). In this way, disruptive innovations are a powerful means to expand and develop new markets, breaking existing market linkages (Adner, 2002; Christensen, 1997, 2006; Christensen et al., 2018; Christensen & Raynor, 2003).

The ecosystem is a collaborative arrangement where companies jointly create value for their customers that could not be created in isolation (Adner, 2006). Ecosystems operate through constantly evolving actors, activities and artefacts, institutions and relationships (Beltagui et al., 2020). An innovation ecosystem is based on the development of a technology (Ansari et al., 2016; Sandström, 2016) and emphasizes collaboration, complementarity and competition between actors around technological artefacts (Granstrand & Holgersson, 2020). On the other hand, the business ecosystem represents an environment in which the company must monitor and react (Li, 2018) to adapt to emerging technologies and business ideas (Adner & Kapoor, 2010). Gomes et al. (2018) point out that innovation ecosystems are more related to value creation, while business ecosystems are more related to value capture.

In the ecosystem, the development of a market and an economy around innovation occurs, operated by business models that sew the value network in a co-evolutionary dynamic of permanent exchange with environments for continuous innovation (Hou & Shi, 2020; Ma et al., 2018). From a systemic perspective, ecosystems are complex and adaptive systems with the capacity to evolve, where cooperation with external actors for complementary innovation resources can contribute to cultivating nascent innovation (Geels, 2002; Gu et al., 2021). Eventually, as disruption evolves in the ecosystem, there may be a transition from a closed ecosystem with little interdependence to a more open ecosystem, spilling over into other members. Disruptions usually do not comply with existing regulatory norms, technological standards and infrastructure; therefore, they can affect the entire value structure of an ecosystem (Chan & Fung, 2016). To this end, the value proposition of the disruption business model can lead to competition in the core market, or it can create a new market and, consecutively, a new ecosystem. In this way, companies are linked to an ecology of value and must align their strategies for ecosystem success (Bers et al., 2012; Moore, 1993; Zalan & Toufaily, 2017) and disruption within the ecosystem (Dedehayir et al., 2017).

2.2. Disruptive Ecosystems

As disruptive innovations are usually developed and commercialized in ecosystems and not in isolated companies, fundamentally, the two themes intersect (Palmié et al., 2019). Palmié et al. (2019) presented the concept of the disruptive innovation ecosystem. The concept combines the definitions of disruptive innovations and innovation ecosystems so that an ecosystem develops and grows around an innovation. When disruptive innovation enters an ecosystem, complementary innovations from ecosystem members can increase the innovation's appeal and emphasize the disruption's potential to dominate the market. Thus, business models draw the perspective of inserting the disruption of the innovation ecosystem and become an essential tool for the demand for the co-evolution of business strategies (Kumaraswamy et al., 2018; Rabin et al., 2020).

In this proposal, an existing ecosystem can be shaken by a disruption, causing creative destruction of the existing ecosystem to generate a new ecosystem based on the value proposition and the disruption business model (Dedehayir et al., 2018; Palmié et al., 2019). In this way, the destruction of the existing ecosystem based on a new technology can lead to the entry of new operators in the emerging market (Adner & Kapoor, 2016). The competition between companies for market share, a dominant design or better partnerships is part of the business models that design the new ecosystem. Thus, due to disruption, new products or services are targeted at a different audience than the traditional one, creating new markets and new customers (Markides, 2006) and shaking the entire existing ecosystem. For disruptors, the task is to unite a new ecosystem around disruptive innovation to gain access to complementary resources from those responsible for the ecosystem they disrupt (Kumaraswamy et al., 2018).

2.3. Disruptive Ecosystem Prediction

This perspective of innovative trajectory change suggests conditions to explore the circumstances in which disruption may occur. Christensen (2006) provides some ex ante examples of how the disruption model organizations should pay attention to: (1) a technological concept of a product that has not yet been developed or is under development; (2) a new technology that starts to be manufactured and commercialized; (3) the threat of an innovation that has not yet affected the mainstream market; and (4) the possible future strategy to respond to the possible ongoing disruption. In all cases, the predictive model aims to contribute to a disruption.

Nicolaï and Faucheux (2015) present some characteristics that can lead to a disruption: (1) the emergence of new technological waves; (2) the introduction of new technology by marginal or non-market actors; and (3) the introduction of a new learning curve from the new technology. According to the authors, for the creation of new markets, there must be a virtuous circle of demand for the new possibilities of the new technology and the technological impulse provided by the new products.

To disrupt dominant ecosystems, it is necessary to introduce more advanced technologies with the potential to break the established bonds of complementary ecosystems and prospect technological leaps (Ozalp et al., 2018). Blume et al. (2020) suggest that an ex-ante idea of performativity and disruption must follow an evolutionary path. Thus, the probability of a disruption materializing with high impact is more significant if the favourable conditions of the context in which the market operates meet a specific gap in the market (Klenner et al., 2013).

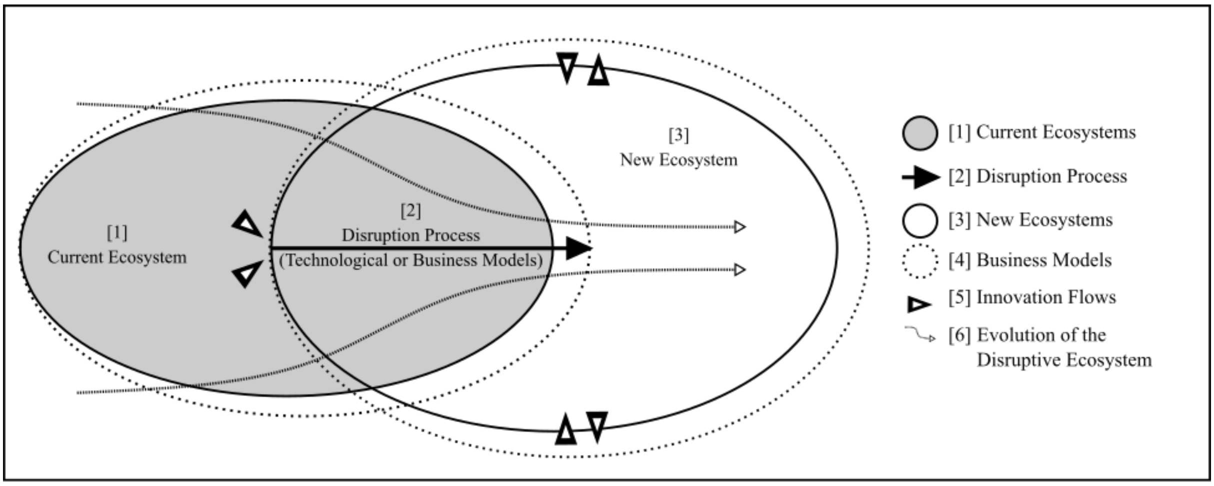
These perspectives allow exploring the complexity of disruptions that cannot be fully predicted or understood. According to Christensen et al. (2018), this would require the identification of factors that shield some markets and factors that are underexploited by the main market and that make specific sectors vulnerable to disruptions. However, adopting a performative perspective of predictability is more likely to learn, take action, and adjust activities in the face of a disruptive phenomenon (Kumaraswamy et al., 2018). In this sense, when disruption drives the rapidly changing business environment, the actors of disruption must not neglect the power of the forces that build and transform ecosystems. Invariably, this disruptive innovation will affect the entire ecosystem, affecting the disruption's development.

2.4. Evolution of the Disruptive Ecosystem

Although different authors have discussed the ex-ante perspective (e.g. Blume et al., 2020; Chen et al., 2016; Govindarajan & Kopalle, 2006; Keller & Hüsig, 2009; Klenner et al., 2013; Müller & Kunderer, 2019; Schoemaker & Mavaddat, 2000; Sood & Tellis, 2011), they present the technology or innovation already inserted and in some degree of market maturity (S-Curve). Therefore, it is not as effective in cases of technologies, ecosystems and markets in the early stages of development and projection. To this end, the proposal by Silva and Grützmann (2022) considers the creation of an innovation or potentially disruptive technology to shake up the entire ecosystem. The authors' proposal makes it possible to present the potential for disruption of technologies at a more embryonic stage and with an impact on internal and external factors of the ecosystem of technologies that are still being developed.

The Disruptive Ecosystem Evolution Model is based on the impact of Disruptive Technology (Christensen et al., 2018; Christensen & Raynor, 2003) on the Ecosystem (Adner, 2017; Granstrand & Holgersson, 2020; Moore, 1993; Palmié et al., 2019) and Business Models to interweave this dynamic (Christensen et al., 2018; Palmié et al., 2019; Petzold et al., 2019). According to the proposal, disruptive innovation has the potential to transform the entire ecosystem, and it is up to actors, innovations and value to co-evolve through business models (Silva et al., 2023 – Article 4).

Figure 1 - Theoretical Evolution of the Disruptive Ecosystem Framework.



Source: Silva e Grützmann (2022).

In the model (Figure 1), the forces interact with the impact of disruption on the evolution of a new ecosystem. Thus, when a disruption occurs in an existing ecosystem, it can evolve into an innovation ecosystem around the disruption. A new market emerges based on the new technology, which requires a new business model configuration. The model presents this disruption process as the destruction of existing technologies and business models for the evolution of ecosystems.

3. Methodology

According to Christensen (2006) and Christensen et al. (2018), it is possible to use a disruptive innovation as an ex-ante model for developing an innovation in the market. In this sense, the strategic analyses developed for a disruptive technology scenario seek to identify opportunities and threats that can reconfigure the business model and the existing market (Petzold et al., 2019). To this end, a perspective of adopting scenarios and performative prospecting of possible business models can help organisations' learning, decision-making and flexibility (Kumaraswamy et al., 2018).

According to the objective, this study is characterized as inductive and exploratory (Bohnsack et al., 2015, 2021; Eisenhardt & Graebner, 2007; Ozalp et al., 2018; Yin, 2009). As a research strategy, we apply the case study based on the technology of eVTOLs in the transportation mobility market. We justify the analysis of this case because the theory of disruption has many dimensions. The analysis of cases shows rich data, making the theory more profound and practical (Christensen, 2006).

This method is proper when existing theories do not answer the existing question and when the question relates to a process or evolution over time (Hannah & Eisenhardt, 2018; Langley, 1999). Finally, we apply the exploration of scenarios since they will be used to understand the future AAM ecosystem. This method was used as an analytical lens to capture the disruption's evolution and build scenarios (Blume et al., 2020). It also allows answering the research question based on the technological changes that are happening and that will have the potential to happen in the market.

3.1. Data Collect

Under the light of ecosystem and disruptive innovation theories, this study analyzes the ecosystem factors, the disruption process, business models, innovation flows, the evolution of the disruptive ecosystem, and the possible arrival of a new market. We followed the example of previous studies (Bohnsack et al., 2015, 2021; Holgersson et al., 2018; Ozalp et al., 2018) to select the bases for data collection.

We use secondary data as an empirical basis for the case, which can contribute to the triangulation of a wide range of sources regarding the development of the disruptive ecosystem of eVTOL technology. The data includes 17 reports provided by technology development companies and 31 reports by specialized consulting companies. A total of 48 reports with 2,427 pages of documents for analysis (Holgersson et al., 2018; Langley, 1999; Ozalp et al., 2018). We also use the eVTOL Insights podcast, which specializes in the eVTOL ecosystem and interviews several CEOs and Directors of large companies and startups in the sector. A total of 77 podcasts containing 29 hours and 54 minutes were analyzed.

We used the list of the largest companies in the world pointed out by Silva et al. (2023 – Article 2) to list the companies that develop eVTOL technology. Following the example of previous studies (Bart, 1998; Campbell, 1991; Lynn & Akgu, 2001; Raynor, 1998; Waddock & Smith, 2015), 10 commercial websites of technology development companies were analyzed. Complementarily, we use the TNMT Innovation Hub list, which points out the leading players in the Aviation sector (6), the Automotive sector (7), the Technologies sector (5) and the main Startups (11), and the list of the top 20 companies in the total amount of technology patents (Lufthansa Innovation Hub, 2021). In total, we collected information from 46 websites of companies related to the development of technologies. A total of 171 documents that could contribute to the technological development and the eVTOL ecosystem were analyzed.

We propose using the Disruptive Ecosystem Evolution tool to model the innovation ecosystem by identifying the relevant constructs and relationships to represent the ecosystem of the current technological world, the impact of disruption and the constitution/evolution of the new disruptive ecosystem. Data analysis will be carried out to describe the potential disruptive process caused by the new technology in an existing ecosystem.

3.2. Data Analysis

The analysis of this article focuses on the insertion of new technology in the existing ecosystem. The concept of Disruptive Ecosystem Evolution tries to assess the impact of disruptive innovation on an ecosystem even before the new technology of eVTOLs is introduced in the market. After analyzing the structure of the existing ecosystem through the collected documents from an ex-post perspective, we apply the collected data to the model. The study is an illustrative case for applying an actual model of inserting new technology into an existing ecosystem and, therefore, a perspective view of disruption. This is the first evaluation of the Disruptive Ecosystem Evolution Model from a prospective perspective.

The focus was on understanding the insertion of disruption in the ecosystem and the consequent evolution of the new disruptive ecosystem. After collecting the data, we performed a content analysis where the emerging patterns of the case studied were identified (Yin, 1994). We follow up on individual cases to verify emerging patterns (Eisenhardt & Graebner, 2007). The concentration of information corroborates with the multiple data sources. The results were categorized into the categories predetermined by the Disruptive Ecosystem Evolution Model to identify the evolution of the existing ecosystem and the disruption insertion logic.

4. Results and Scenarios

The following results will be presented based on the Disruptive Ecosystem Evolution Model and the analysis carried out. The first step contextualizes the researched case, and for each step of the model (Current Ecosystem, Disruption Process, New Ecosystem, Business Model, Innovation Flows, Evolution of the Disruptive Ecosystem), the possible evolution of the ecosystem in the face of disruption and possible scenarios of construction of this ecosystem. We approach a discussion of the current context and point out the possible ex-ante scenarios of disruption in the ecosystem. Some quotations from the research were used to present the results and are marked in parentheses. The complete table is presented in Annex I.

4.1. Technology Case Background

Many prototypes and projects of "flying cars" were part of the historical development of this technology (61; 4; 60; 70). Despite numerous attempts, there was no technological and market maturity to take on this change nor an ecosystem that allowed the technology to grow (14). However, with frequent problems related to combustion and congestion problems, among others, eVTOLs have become a proposal for new market demands (72; 67; 16; 30; 32; 42; 70; 18).

With the rise of electric batteries to power vehicles, eVTOLs would become cleaner, more economical and cheaper technologies (53; 36; 37; 25; 39; 27; 76). Vehicle automation technology has also contributed to air vehicles, allowing them to become safer, faster, and more efficient, without noise and pollutant emissions, to work intelligently, to seek new transport routes that are flexible, accessible and entirely on demand from users (60; 11; 67; 16; 39; 43; 62). An evolution of the innovation ecosystem in search of the development of eVTOLs technology (11; 14; 71). That provides new ways of delivering goods and services and can deliver new transportation mobility solutions (60; 72; 18; 9).

The eVTOL will combine electric propulsion, autonomous navigation, vertical lift and other communication and navigation features, and user input is limited to commanding the desired trajectory. Combined with electrification and automation technologies, the vertical propulsion of vehicles could propose the exploration of airspace as a new route for AAM. Without the need for runways, passengers and goods will depart from take-off and landing platforms positioned at different locations in the city, and aircraft, including drones, will be able to coexist safely and quickly (60; 72; 18). Compared to other forms of urban transport, eVTOLs can develop travel routes in real-time airspace by shortening the distances travelled at much higher speeds and shortening the duration of trips compared to land transport (8; 67; 43). With the advent of the potential disruption of eVTOLs, there may be a reduction in the need for roads, maintenance costs and congestion, allowing the construction of take-off and landing stations (60; 36; 15; 72; 18). The focus of eVTOL is to offer a new class of aircraft that will revolutionize inter- and intra-city movement, providing fast, direct and clean mobility (70).

While introducing eVTOLs to the market has brought gains, some concerns are considerable. Certification and regulation processes will be necessary to adapt to the new reality (67; 31; 24). New traffic control rules will need to accommodate eVTOL routes in the airspace close to large aircraft and smaller drones. Cybersecurity issues also concern new technology (16; 14; 13). A structural change needs to be made to the transport infrastructure to suit the construction of vertiports, eVTOL take-off and landing bases (66; 46; 72). Other important factors are vehicle reliability and demand for transport via eVTOLs, where this mode of transport needs to become competitive to reach public acceptance (60; 66; 23; 24; 34; 35; 40; 41; 44). All these barriers are part of the ecosystem impacted by new technology. As these barriers are overcome, the AAM industry has the potential to offer transportation mobility solutions and economic, social and environmental opportunities. For the development of this future, intelligent, connected, sustainable and publicly accepted traffic management solutions will only emerge through the collaboration of the entire ecosystem (1; 6; 28; 65; 60; 18; 9; 50; 58; 67; 55; 59).

For eVTOLs integration into the market, aircraft need to be equipped with information to navigate safely through the airspace, share information and deal with the airspace's large and diverse population density. Several companies, especially startups, are developing eVTOL technology to make it a reality. From incumbents in various markets such as Boeing, Airbus, and Embraer in the aviation sector, Toyota, Porsche and Hyundai in the automobile sector, to startups such as Volocopter, Joby Aviation, and Ehang, among others (8; 1; 19; 71; 64; 50; 76; 55; 16).

However, it is important to understand that eVTOLs will not compete in range with conventional cars, trains, helicopters or planes. eVTOLs should offer an alternative form of air transport that complements the Transportation Mobility System (66; 60). In this perspective, considering that eVTOLs are a technology that can change and even create a new business model in the transportation mobility market, this is a technology with the potential to create a new ecosystem of disruptive innovation (74; 33; 62; 29). The AAM ecosystem is taking shape. This embryonic market is now open to potential participants from various backgrounds. It can attach importance to different aspects, such as the production of technologies, infrastructure development, navigation, air traffic management systems, among others. As technologies mature, they require collaboration between governments and businesses to create new regulatory and infrastructure frameworks to facilitate future development (1; 17; 6; 28; 65; 60; 18; 9; 50; 58; 67; 55; 59). The picture of eVTOLs ecosystem potential disruption emerges with the relationships between its different stakeholders and their challenges to overcome. This disruption can create a new AAM ecosystem based on eVTOLs with a focus on air mobility as an on-demand service, transform the entire transportation experience and become the solution to many environmental, economic and social problems generated by current ICE technology.

4.2. Current Ecosystem

The current Ecosystem is the one in the actor coexist and are affected by the disruption. The current innovation ecosystem in the transportation mobility sector is formed by ICE manufacturing companies that are evolving towards the entry of EVs, such as Toyota, Nissan, Hyundai, among others, and by companies entering the sector, such as Tesla (71; 63; 50; 69; 10; 57; 57; 57; 75). The sector also focuses on the production of batteries for electric vehicles. On the other hand, the innovation ecosystem in the air mobility sector is made up of aviation manufacturing companies, such as Embraer, Boeing, and Airbus, and helicopters, such as Honeywell, Bell, and Leonardo (19; 8; 1; 49; 7; 58; 48; 50; 64; 1; 8; 61; 60). Ecosystems have their limits well separated from each other, with companies distinguishing in the production of technologies and the exploration of markets. The scenario of the new technology of eVTOLs points to a disruption in the existing innovation ecosystem in both markets. Specifically, for the innovation ecosystem, the technology of eVTOLs tends to encourage an evolution of established actors and the insertion of new actors to accompany the evolution of the Ecosystem itself and the creation of the new market (55; 21; 76; 56; 5; 60; 70; 58). For the business ecosystem, both sectors will have a new competitor for short and medium-distance transport that complements the transportation mobility ecosystem (66; 22; 60).

4.3. Disruption Process

The disruption process occurs when a new technology and a new business model affect the existing ecosystem. The disruption in the current ecosystem occurs when combining transportation mobility electrification and automation technologies with air mobility propulsion technologies, opening up space for the development of the new AAM ecosystem (55; 21; 76; 56; 5; 60; 70; 58; 72; 18). Due to the growing movement of actors seeking to leverage this new technology, eVTOLs have a disruptive impact on the current innovation and business ecosystems in the terrestrial mobility and aviation sectors. For the innovation ecosystem, due to the need to master the different technologies required (e.g. electric batteries, automation, propulsion, connectivity, artificial intelligence, cloud computing, big data, 5G), where companies do not have to master all skills necessary for the development of the eVTOL. This scenario points to the maturation of the new technology, accompanied by several actors from the automotive and aerospace sectors and several new actors from other sectors (66; 60; 70; 12;

74; 6; 67; 16). Due to the need to master the wide range of necessary skills, many companies are establishing partnerships to explore these technologies.

In this new AAM context, startups dominate technology development and drive market development. Joby Aviation, Volocopter and Lilium are examples of startups pioneering the technology and market of eVTOLs (71; 50; 55; 59; 76; 7; 58; 60; 13). The entry of new players into a new ecosystem accentuates the impact of disruption. The number of patents and investments related to the development of technologies has grown a lot in recent years, and startups and their partners have dominated this expansion. Ehang and KittyHawk are two startups with the highest patent filings growth rate (71; 50; 55; 16; 56; 60). Due to this technological diversity, as there is no dominant design or a defined exploration business model, many new entrants seek space for a slice of the market. The scenarios point to constant collaboration between incumbent operators from the various technological segments with startups for developing eVTOL technology and the AAM market (6; 28; 65; 60; 18; 9; 50; 1; 58; 67; 55; 59). Another scenario is the pull of the disruptive process due to the massive collaboration of so many companies from various sectors, creating a participatory network effect in search of technological maturity.

For the business ecosystem, scenarios point out that eVTOL technology tends to complement the transportation mobility ecosystem, where transport technologies will coexist, and an integrative experience between air and land transport should occur (66; 22; 60). eVTOLs tend to be used for medium and short trips, coexisting with aeroplanes for long trips and with cars for short trips. The cars will complete the eVTOL route, being responsible for the first and last miles of the trips. While technology coexistence scenarios are relevant opportunities for all participants, the risks are greater for traditional helicopter companies. The eVTOLs will be more sustainable technologies, with low noise emissions and competitive cost with traditional cars, and will create the on-demand short and medium-haul air transport market. This approach tends to incorporate the high-cost market for helicopter travel, which points to an imminent disruption of this market. In preparation for this disruptive trend, many manufacturers like Honeywell, Bell, and Leonardo are engaging in developing eVTOLs to keep up with the disruptive process (49; 7; 58; 1; 60; 11; 37; 38; 26).

4.4. New Ecosystem

The new ecosystem emerges based on the interaction of actors and technologies to create disruption. With the arrival of automation software technologies, connectivity, 5G, the internet of things, artificial intelligence, cloud computing, big data, among others, the transportation mobility ecosystem was taken over by companies from different sectors. Traditional car manufacturing companies like Toyota, Nissan, Hyundai; and new entrants to the automation sector like Tesla and Uber; and aviation giants like Embraer, Boeing and Airbus; helicopter manufacturing companies like Honeywell, Bell and Leonardo; in addition to technology companies such as Google, IBM, Tencent and Intel; and retail companies such as Amazon and the Alibaba Group, join startups such as Joby Aviation, Lilium, Eve, Volocopter, Ehang, among others, to develop technologies (71; 63; 50; 69; 19; 8; 49; 7; 51; 68; 52; 3; 55; 59; 21; 76; 16). These companies joined the traditional vehicle manufacturing ecosystem and co-evolved through coopetition for the development of the electric and autonomous AAM sector.

To reach the business ecosystem, the new technology support ecosystem is critical to AAM's success. The infrastructure is necessary for the operation of eVTOLs and creates a bottleneck for ecosystem actors to interact in the operational development of the technology (66; 46; 72). Companies like Embraer/EVE partner on all continents to develop the necessary infrastructure for operations (18; 21). Failure to develop the right infrastructure can create bottlenecks and impede AAM's growth. Linked to infrastructure, service flows are an important point that will ensure the safety and efficiency of transport activities. Many new startups seek to benefit from this growing infrastructure to have space in the market. Another critical point is the advancement of regulations that legalize and encourage the technology commercially (67; 31; 24). The Uber Elevate project carried out regulatory-friendly development mates (72). Finally, public acceptance, presenting the benefits of speed, economy, and a safe, pleasant, and environmentally green integrated mobility experience, will directly influence market demand (60; 66; 23; 24; 34; 35; 40; 41; 44). For this, the AAM business ecosystem must bring together stakeholders from various sectors, constituting an ecosystem composed of companies, government agencies, research and technology organizations, academia, professional institutions, local authorities, social scientists, and consumers (17; 6; 28; 65; 60; 18; 9; 50; 1; 58; 67; 55; 59).

The scenarios for the innovation ecosystem are certainly related to collaboration between the various stakeholders for technology development. Not far away, due to the diverse technologies needed to realize the objective of eVTOLs and AAM, scenarios also point to different designs dominating different markets (6; 28; 65; 60; 18; 9; 50; 1; 58; 67; 55; 59). Different technologies can take the lead and develop the various available markets from the various specifications and relationships of governments, companies, legislation, and infrastructure. These multiple constitutions can occur to the detriment of the dominant technological design. Everyone who best integrates into existing transportation mobility will have a chance to grow in the market.

4.5. Business Model

Business models create the alignment of actors and technologies within the ecosystem. With the arrival of electrification and automation technologies, the technologies and markets of the transportation mobility and aviation ecosystems began to have points of intersection. The scenarios point to collaboration between incumbent operators from various sectors and new entrants to develop an innovative ecosystem. Joby Aviation acquired Uber Elevate (responsible for Uber's UAM sector) and has partnerships with Hyundai and Toyota to develop the technology (55; 73; 50; 71). Embraer created EmbraerX and EVE as spinoffs for technology development and market exploration (19; 20; 21). Google acquired KittyHawk to leverage its technologies in favour of the AAM market (2; 56). Kittyhawk teamed up with Boeing and created a joint venture (Wisk) to develop the Cora (56) aircraft. In addition to their "isolated" developments, many of these companies collaborate. This new, complex, and sophisticated ecosystem will take years of planning to develop, and collaborations seem to be the most direct path to technology and ecosystem success.

Due to the ease of diversification of startups, incumbent operators and giants of the various markets do not seek to be the first in developing eVTOLs and AAM. Large companies know that the market needs to be mature for the new technology (60; 13). Vehicle development, infrastructure networks, regulation, and public acceptance, need to be in place. That is why many of these companies choose to encourage the ecosystem through partnerships, acquisitions, mergers, and joint ventures. Startups tend to be more malleable, faster, and more susceptible to the changes that the development of new technology demands from companies.

While actors cooperate in the collaborative innovation ecosystem to develop eVTOL technology, the exploration of the ecosystem still needs to be defined by the lack of a dominant design and a clear business model (1; 60; 66). Within the market, the business ecosystem runs into problems with the legislation, strong restrictions from traditional markets, lack of investment (even at low growth), and difficulty in accepting customers.

4.6. Innovation Flows

The innovation flows of a business model are part of the process and can interact with the disruption in changing the ecosystem. Another characteristic of the business model that emerges is the model of open innovation and closed innovation. Companies like Hyundai invest heavily in a complete line of eVTOLs for different needs and markets. The company takes a holistic approach, looking at all aspects of the market, from development, manufacturing, and infrastructure, as a strategy to shape and influence ecosystem directions. Hyundai prioritizes partnerships with other companies and avoids direct investments in startups to build a robust and comprehensive approach to developing technologies, infrastructure, and business models (60; 70; 4; 50; 42).

On the other hand, more open business models allow companies to use partners' expertise to advance innovation. For example, the collaboration between Toyota and Joby Aviation, where Toyota offers all the production capacity, quality and cost control experience, and market exploration, while the startup presents its innovative and agile capacity for technology development (71; 55; 6070; 45). 75wagen and Leonardo, companies in the automotive and aerospace sectors, respectively, cooperate with several laboratories, universities, and innovation centers in several countries to make local connections and gain regional knowledge for the development of technology in the Deep Tech area (75; 58; 60; 70). Innovation centers in various regions aggregate local knowledge and experience and provide the many partners with the ideal infrastructure to derive global solutions to regional challenges and needs.

4.7. Evolution of the Disruptive Ecosystem

Disruptive Ecosystem Evolution occurs when actors leverage new technologies and evolve into a new ecosystem based on disruption. The technologies and markets of the transportation mobility and aviation ecosystems were well-defined and separate. This is the initial ecosystem and the basis of transportation mobility. The disruptive process begins with the arrival of electrification, automation, and connectivity technologies developed by incumbent operators in the two sectors, and by new entrants to the technology sector, the sectors have come together. The companies participating in these initial ecosystems evolve with the new participants in the new ecosystem of eVTOLs (11; 14; 71; 47). For the development of the entirely new ecosystem to occur successfully, the major players join new entrants to collaborate in technology development (48; 50; 64; 1; 8; 61; 60). At this point, open innovation flows prevail to mitigate risks and increase the chances of success.

In the development of eVTOLs technologies, ecosystems mixed and formed an ecosystem cluster with actors and technologies transiting between several different ecosystems. For example, the manufacturing capabilities of automobile companies such as Toyota, Nissan, Hyundai, and Volkawagen; the aerospace sector such as Embraer, Boeing, Airbus, and Bell; which have partnerships with many startups such as Joby Aviation, Lilium, and Volocopter; and which use the same software as technologies developed by Google, IBM, and Amazon (71; 63;

50; 75; 19; 8; 1; 7; 55; 59; 76; 2; 51; 3). Companies such as Toyota or JetBlue, among others, invest in eVTOL startups to gain access and learn about new technologies potentially relevant to their core businesses (71; 54). Meanwhile, for technology companies like Tencent or Intel, eVTOL commitments unfold a whole new business segment where they can leverage many existing software capabilities in the future (68; 52). In this accumulation of partnerships, a biome of innovation for eVTOLs and the AAM market emerges (It will be better discussed in topic 5).

The scenario here points to the growth in the number of participants in the ecosystem, greater investments in development and consequent technological maturation. Many collaborative projects attempt to mature the technology and explore the market (48; 50; 64; 1; 8; 61; 60). Because they are more dynamic and agile, startups tend to accelerate the development of technologies. Incumbent companies tend to use their resources, encourage the development of technologies and infrastructure, and collaborate with startups to mature the field (71; 50; 55; 59; 76; 7; 58; 57; 75; 56; 60; 70). Many collaborations between manufacturers, operators, infrastructure providers and regulators are needed for the technology to be pushed into the market (6; 28; 65; 6018; 9; 50; 1; 58; 67; 55; 59).

For the business ecosystem, adaptation to environmental, economic and social needs is part of the selection process of technologies to dominate the market and the consequent public acceptance in the AAM market (6; 28; 65; 60; 18; 9; 50; 1; 58; 67; 55; 59). After reaching the biome's peak, the ecosystem becomes complete and operational. When the eVTOLs technology maturity is reached, the main scenario points to the beginning of the competition to the detriment of collaboration (14; 30; 60). eVTOLs will be a technology that will create a new form of transportation mobility as an on-demand service and will integrate the broad existing mobility system (66; 60; 11; 67; 16; 39; 43; 62). At that point, the AAM business ecosystem becomes the focus more than the innovation ecosystem.

5. Discussions of Scenarios with the Literature

The AAM ecosystem is at an early stage, creating and developing distinct characteristics from the current transportation mobility system. Characteristics such as ways of producing technologies, infrastructure development, regulatory structures, connectivity systems, artificial intelligence, and navigation, air traffic management systems, new ways of providing services, creating environmental, economic, and social solutions, and transforming the experience of transport, among others, which become part of the AAM system. This finding is in line with the literature where disruptions have a set of characteristics different from the dominant technologies in the market (Bower & Christensen, 1995; Christensen, 1997, 2006; Christensen et al., 2018;

Petzold et al., 2019) and has the potential to reshape the way companies and industries operate (Christensen et al., 2018; Kumaraswamy et al., 2018). This ecosystem change is an indication of a disruption that can create a new AAM ecosystem based on eVTOLs and is in line with the literature where disruptions create demand for new customers, break existing market linkages and, consecutively, create space for new markets (Adner, 2002; Christensen, 1997, 2006; Christensen et al., 2018; Christensen & Raynor, 2003; Markides, 2006; Palmié et al., 2019). In this way, research was carried out on the impact of disruption on the transportation mobility ecosystem, which is also in line with the literature where disruptions are developed and marketed by ecosystems (Ansari et al., 2016; Kumaraswamy et al., 2018). Also in line with the literature, in this researched case study, we see the impact of the development of a technology on the innovation ecosystem (Ansari et al., 2016; Sandström, 2016) and the environment to which companies must monitor and react as an ecosystem of business (Li, 2018).

The current innovation ecosystem in the transportation mobility sector is being affected by new technologies, specifically eVTOLs, which could create a new AAM market. eVTOLs tend to encourage the evolution of established actors and the insertion of new actors to accompany the evolution of the ecosystem itself. This result corroborates the literature where innovation ecosystems are collaborative arrangements so that companies can jointly make major innovations in the market (Adner, 2006; Holgersson et al., 2022; Yaghmaie & Vanhaverbeke, 2019). For the business ecosystem, eVTOLs are a complementary tool in the current transportation mobility ecosystem. This result is in line with the ecosystem literature, where changes are an environment in which the company must monitor and react (Li, 2018) to adapt to the development of emerging technologies and business ideas (Adner & Kapoor, 2010).

The disruptive process brings electrification, automation, and air propulsion technologies together and opens space for developing the new AAM ecosystem. These results also corroborate the literature where the occurrence of disruption can transform the entire structure of an ecosystem (Ansari et al., 2016; Christensen et al., 2018; Kumaraswamy et al., 2018; Lee & Shin, 2018; Palmié et al., 2019; Rabin et al., 2020; Salvador et al., 2019; Zalan & Toufaily, 2017). Due to the need to integrate different technologies, many technology operators integrate eVTOL development. This entry of new participants into a new ecosystem accentuates the process of disruption. The scenarios point to constant collaboration between all actors for the technological development of eVTOLs. These findings also corroborate the literature where disruption tends to cause an evolution dynamic (Holgersson et al., 2022), replacing current standards with new technologies (Gu et al., 2021). For the business ecosystem, the scenarios point to the coexistence and integration of technologies in urban transport. This same finding is in line with some disruption theories where technologies can create a new market (Christensen et al., 2018; Kumaraswamy et al., 2018) and is in line with other disruption theories where technology tends to supplant current technology (Bower & Christensen, 1995; Christensen, 1997).

The new disruptive ecosystem is based on the interactions between actors and technologies. The different connectivity technologies, 5G, the internet of things, artificial intelligence, and automation, among others, encouraged the entry of several technology providers into the transportation mobility industry. These companies are co-evolving with the traditional ecosystem to develop the AAM sector. Various government relationships, companies, legislation, and supporting ecosystem infrastructure are critical to creating the framework for the growth of the AAM market. This result corroborates the literature where, in the ecosystem, the development of a market and an economy around innovation occurs (Hou & Shi, 2020; Ma et al., 2018). The literature also points out that support factors are critical for the development of ecosystems. Thus, as the literature points out, ecosystems are complex and adaptive systems with the capacity to evolve, where cooperation with external and complementary actors can contribute to cultivating innovation (Geels, 2002; Gu et al., 2021). This fact is necessary for the development of the eVTOL ecosystem.

Business models link all the different actors, technologies and business models in each market. The most evident business model is the collaboration between all participants for technology and ecosystem development. This finding corroborates the literature where business models draw the perspective of inserting the disruption of the innovation ecosystem and becoming a tool for the co-evolution of companies' strategies (Kumaraswamy et al., 2018; Rabin et al., 2020). Many companies encourage the ecosystem through partnerships, acquisitions, mergers and joint ventures. Startups tend to be more malleable, faster and more susceptible to the changes that the development of new technology demands from companies. Incumbents utilize their resources and provide efficiency, productive capacity and market experience to the growing market. This finding also corroborates the literature on disruptive ecosystems, where an ecosystem shaken by disruption can generate a new ecosystem based on the disruption's value proposition and business model (Dedehayir et al., 2017; Palmié et al., 2019). Part of the process is to unite ecosystem actors for successful disruption (Kumaraswamy et al., 2018).

Open innovation flows are another feature of the business model that interacts with disruption in the evolution of the ecosystem. More open business activities allow the use of partner resources to develop innovation. This open relationship between actors corroborates the literature on technology, ecosystem and market development (Chan & Fung, 2016; Rabin et al., 2020). This openness also corroborates the literature where companies that integrate the ecosystem are a value ecology and must align their strategies for ecosystem success (Bers et al., 2012; Moore, 1993; Zalan & Toufaily, 2017) for the development of disruption within the ecosystem (Dedehayir et al., 2017; Palmié et al., 2019).

Lastly, the evolution of the disruptive ecosystem occurs when actors and technologies evolve into a new ecosystem based on the disruptive technology. The new ecosystem will only evolve and become disruptive if the initial ecosystem is changed. Thus, the disruptive process begins with the arrival of electrification, automation, connectivity and air propulsion technologies, and the actors of the initial ecosystems evolve into the new ecosystem of eVTOLs. These results corroborate the literature to help understand how existing ecosystems are affected by disruptive innovations (Ansari et al., 2016; Oghazi et al., 2022; Ozalp et al., 2018) and how it evolves into the new disruptive ecosystem (Dedehayir et al., 2017; Palmié et al., 2019; Silva & Grützmann, 2022). This study also supports an understanding of the potential of disruptive innovations to disrupt existing ecosystems (Christensen et al., 2015; Oghazi et al., 2022; Palmié et al., 2019; Silva & Grützmann, 2022). The actors and technologies of eVTOLs and ecosystems mixed and formed an ecosystem cluster in search of maturing the technology and exploring the market.

Digging deeper into this ecosystem innovation cluster, inspired in the biologic concepts (Keith et al., 2022), we suggest the concept of the innovation biome, where all actors with different ecosystem focus come together to collaboratively develop eVTOL technology, and with is the set of different technological and non-technological ecosystems involved to develop demand for the AAM market. The results of this research corroborate the proposal of the biome concept and the theory that the new disruptive ecosystem obtains access to resources from all the actors responsible for the ecosystem they disturb (Kumaraswamy et al., 2018). The innovation biome creates space for complementary businesses from all ecosystems based on different technologies to grow the core technology ecosystem. In this study, the leading technology is eVTOLs, and the different technologies (e.g. automation, connectivity) are necessary parts of the biome. The technologies needed for the core technology have their ecosystems but are part of the eVTOL innovation biome. The success of the eVTOL disruptive biome depends on the success of each technology ecosystem within its own biome. Thus, our results also propose an evolution of ecosystem theory (Bers et al., 2012; Moore, 1993; Zalan & Toufaily, 2017), where the success of the disruptive biome depends on the alignment of successful ecosystem strategies and the disruption within the ecosystem.

For the business ecosystem, our results point to a broader space surrounding different technology sectors in search of successful disruption. By joining the different ecosystems and after reaching the peak of the biome, the ecosystem tends to become complete and operational. When the technology maturity of eVTOLs has been reached, competition between companies will become greater than collaboration. At this point, the AAM business ecosystem becomes the focus as the innovation ecosystem, and companies' competition for market share, dominant design or better partnerships becomes part of the business models that design the new ecosystem. From the perspective of the ecosystem literature, the development of a market and an economy around innovation occurs in a co-evolutionary dynamic of innovation ecosystems (Hou & Shi, 2020; Ma et al., 2018), as well as occurs from the perspective of the biome of innovation. As complex and adaptive systems with the capacity to evolve are proposed by ecosystem theory (Geels, 2002; Gu et al., 2021), the innovation biome can also contribute to cultivating nascent innovation.

5.1. Theoretical Contributions

This study has important contributions to the literature. First, this study contributes to the understanding of the AAM concept and nomenclature as part of the development of an entire industry and emerging markets for eVTOL technology. Which fits the exploratory objective of this research to understand the insertion of the potentially disruptive technology of eVTOLs and the development of the AAM market (Reich et al., 2021; Reiche et al., 2021). To do so, this study uses the case study of eVTOLs to present the impact of a disruption in an ecosystem. To answer the research question, we conducted a case study to analyze the ex-ante disruptive potential of eVTOL technology. As the construct was based on a theoretical framework, the case study offers an opportunity to (1) apply theoretical propositions identified from the Evolution of the Disruptive Ecosystem Framework, (2) gain new insights from the technologies concerning existing propositions, and also (4) derive new propositions from improving theory building on disruption (Christensen, 2006; Klenner et al., 2013; Yin, 2009). From an analytics standpoint, disruptive ecosystem evolution evaluates ecosystems before disruptions enter the market.

In this way, we contribute to broadening the debate on the impact of disruptive innovations on ecosystems (Ansari et al., 2016; Oghazi et al., 2022; Ozalp et al., 2018) and innovate by including the impact of disruption and evolution of ecosystems. This debate goes further by presenting the insertion of new actors and technologies cooperating in the new urban air mobility ecosystem. In the disruptive ecosystem's proposed evolution/adaptation flow, companies adapt to the new ecosystem, where old and new operators can gain space. Furthermore, adding to the discussion by Silva et al. (2023 – Article 4), the new evolving ecosystem value proposition positively aggregates the ecosystem reorganization and proposition of scenarios for eVTOLs and the AAM market. Hence, disruptive innovation can generate an impact both in the innovation ecosystem and in the business ecosystem and the market.

In turn, this study contributes to the ecosystems literature by deepening the understanding of the evolution of innovation ecosystems that develop disruptive innovations and subsequently grow around this innovation (Palmié et al., 2019). A disruptive ecosystem is created when a disruptive technology and product collide with a disruptive business model. What allows us to associate the disruption of the ecosystem is the predictability found in the change technology impacts on the ecosystem. Furthermore, as far as the authors of this study are aware, no ex-ante studies have sought to understand ecosystem change based on disruption.

This study also contributes to the disruption literature proposed by Christensen (2006) and Christensen et al. (2018), where disruption may have characteristics for predicting ex-ante arrival on the market. We extend this discussion with the impact of ex-ante disruption to the ecosystem. This study raises considerations about the Disruptive Ecosystem Evolution Model (Silva & Grützmann, 2022), which is viable for designing the impact of disruption on the ecosystem. New ecosystem based on disruption. The model has become a viable tool for categorising possible disruption impact scenarios and performing the constitution of the disruptive ecosystem.

In this scenario, this study contributes to distinguishing the radical impact and the disruptive impact on ecosystems. Radical innovations break existing technological standards with the risk of a drastic disruption in the ecosystem. With every abrupt break/destruction, the ecosystem cannot adapt, where the possibility of radical technology failure and the consequent death of many ecosystem actors may occur. Differently, as in the disruptive innovation presented in this study, a change process occurs over time. Disruption only happens when one technology supplements the other, whether over a short or long time. So, disruptive innovation adapts to the ecosystem in a collaborative process between existing actors and new actors that are created, fostering an ecosystem with evolutionary dynamics of technologies, business models and value propositions. Our contribution to the literature with the proposal of an innovation or disruptive biome, where different ecosystems collaboratively develop the eVTOLs technology and where multiple technological and non-technological ecosystems are aligned with the collaborative, adaptive and evolutionary process to develop the AAM market.

This study also raises other considerations about the constitution of the disruptive ecosystem (Dedehayir et al., 2017; Palmié et al., 2019; Silva & Grützmann, 2022). Recent studies point to a change in the value proposition of the mobility ecosystem based on new technologies (Silva et al. 2023 – Article 2). These ecosystem value changes raise considerations for disruption as part of a technological leap. When a disruption impacts an ecosystem, it can evolve in the form of a technological leap for the ecosystem (Silva et al., 2023 – Article 3). This evolutionary leap of the ecosystem can be accompanied by a dynamic value proposition that accompanies the constitution of the new disruptive ecosystem (Silva et al. 2023 – Article 4). Thus, changes in the perspective of value, actors, business models and the value of new technology indicate a propensity for a new ecosystem. This way, a disruptive ecosystem is created when a disruptive technology or product is realized alongside a disruptive business model. Thus, our study presents possible scenarios for the impact of disruption and alteration of the ecosystem pattern and value proposition.

5.2. Practical and Managerial Contributions

Currently, it cannot be said from which direction a future disruptive innovation will occur, although the market is ready for future disruptive innovations (Klenner et al., 2013). Our study contributes in a managerial way so that companies and managers can prepare for possible future scenarios of the arrival of eVTOL technology and the AAM market. It is important to consider the current capacities of the actors and the opening of ecosystem exploration spaces, both for innovation and business. Actors must also pay attention to the forces that build and transform ecosystems. Invariably, this disruption must affect the entire ecosystem and the new AAM market.

Another significant contribution of our research seeks to reinforce the importance of the support ecosystem necessary for developing technology in the market. As companies invest in development and technologies mature, they require collaboration between governments and companies to create new regulatory frameworks, infrastructure, supporting technologies, and user acceptance for market exploitation. This is critical for the birth of any technology, and it is also critical for the AAM market. The technology of eVTOLs is in the early stages of development, as well as the AAM market; it is up to managers to embrace the emerging change that will shape the transportation mobility market.

6. Conclusions

This study sought to identify and to analyze the possible scenarios for the potentially disruptive innovations of eVTOLs and the Advanced Air Mobility ecosystem. It was possible to present the main scenarios for disrupting eVTOLs within the innovation ecosystem and the AAM market. The main results point to the collaboration of actors from different sectors for technology development (Adner, 2006; Holgersson et al., 2022; Yaghmaie & Vanhaverbeke, 2019).

Another significant result of this study was the coevolutionary process (Hou & Shi, 2020; Ma et al., 2018) presented based on the various necessary technologies that converge to the disruptive process of eVTOLs. Actors and technologies associate their strategies for technology success within the ecosystem (Kumaraswamy et al., 2018; Rabin et al., 2020). In this case, ecosystem strategies directed towards developing eVTOLs as a broader scope of different technologies. Thus, we proposed the innovation biome to expand the scope of technologies that involve the different technological ecosystems that are part of eVTOLs.

The Disruptive Ecosystem Model has also proved to be a valuable tool for exploring the impact of a disruption within the ecosystem (Silva & Grützmann, 2022). The tool appropriates the dynamic and evolutionary condition of the ecosystem in the face of disruption and can capture possible scenarios and impacts of the new ecosystem. It was also possible to capture the impacts of the business ecosystem in creating the new AAM market.

6.1. Limitations

Our study is subject to a number of limitations. First, the method consists of exploring the possible scenarios in the official documents analyzed within the perspective of the Disruptive Ecosystem Model. Other analysis models are suggested, and other data sources are used to search for better results. Another limitation was to derive the disruptive potential ex-ante without verifying how its effects unfold in the market. As the technology is still incipient in the market, it was not possible to follow this growth process. It is suggested to monitor the insertion of the technology in the market and make new future proposals for the design of the technology. Another limitation as the technology is in its nascent stage, and the data are a cut of the technological and business model current information, therefore it can change with the appearance of new external forces that can positively or negatively impact negatively affect the disruptive ecosystem. Therefore the information can be expanded and/or changed, which demands further research for this follow-up. It is also suggested research to deepen the universe of AAM for industry development and UAM for development of the urban market. This research has intrinsic limitations of the case study methodology (Yin, 2007) and the exclusive focus on the market and transportation mobility technologies. It is suggested to carry out multiple case studies to test the Disruptive Ecosystem Model and new research methods for eVTOLs and AAM.

Appendix I

Nº	Source	Nº	Source
1	Airbus, 2022 (Official Website)	39	Evtol Insights, 2020 (Podcast: p. 18 – Bruno Mombrinie – Founder and CEO of Metro Hop)
2	Alphabet/Google, 2022 (Official Website)	40	Evtol Insights, 2021 (Podcast: Ep. 37 – Daniel Avdagic of AV Living Lab)
3	Amazon, 2022 (Official Website)	41	Evtol Insights, 2021 (Podcast: Ep. 47 – Yun-yuan Tay, Head of Asia Pacific at Skyports)
4	Asian Sky Group, 2021 (Report: UAM Report)	42	Evtol Insights, 2021 (Podcast: Ep. 48 – Pamela Cohn of Hyundai Motor Group's UAM Division)
5	Autoflight Global, 2022 (Official Website)	43	Evtol Insights, 2021 (Podcast: Ep. 55 – Manal Habib, CEO and Co-founder of MightyFly)
6	Bell Helicopter, 2022 (Official Website)	44	Evtol Insights, 2022 (Podcast: Ep. 68 - Bem Tigner, CEO and co-founder of Overair)
7	Bell, 2022 (Official Website)	45	Evtol Insights, 2022 (Podcast: Ep. 72 - Eric Allison, Head of Product at Joby Aviation)
8	Boeing, 2022 (Official Website)	46	Fukushima, 2019 (Report: Headed towards "Air Mobility Revolution")
9	Daimler, 2022 (Official Website)	47	General Electric, 2022 (Official Website)
10	Deloitte, 2017 (Report: Framing the future of Mobility)	48	Honda, 2022 (Official Website)
11	Deloitte, 2018 (Report: Change is in the air The elevated future of mobility What's next on the Horizon)	49	Honeyweel, 2022 (Official Website)
12	Deloitte, 2018 (Report: Horizon in the air The elevated future of Horizon What's next on the Horizon)	50	Hyundai, 2022 (Official Website)
13	Deloitte, 2019 (Report: Change is in the air The elevated future of mobility)	51	IBM, 2022 (Official Website)
14	Deloitte, 2019 (Report: Change is in the air The elevated future of mobility: What's next on the horizon?)	52	Intel, 2022 (Official Website)
15	Deloitte, 2019 (Report: Horizon in the air The elevated future of Horizon: What's next on the Horizon?)	53	Japan Airlines, 2022 (Official Website)
16	Ehang, 2022 (Official Website)	54	JetBlue, 2022 (Official Website)
17	Ehang, 2022 (Report: The Future of Transportation: White Paper on UrbanAir Mobility Systems)	55	Joby Aviation, 2022 (Official Website)
18	Embraer X, 2020 (Report: Flight Plan 2030)	56	Kittyhawk, 2022 (Official Website)
19	Embraer, 2022 (Official Website)	57	KPMG, 2022 (Report: Levelling Up China's race to an autonomous future)
20	EmbraerX, 2022 (Official Website)	58	Leonardo,2022 (Official Website)
21	EVE, 2022 (Official Website)	59	Lilium Aviation, 2022 (Official Website)
22	Evtol Insights, 2020 (Podcast: Ep. 1 - Lilium's Oliver Walker-Jones, head of communications)	60	Lufthansa, 2021 (Report: Are Air Taxis Ready For Prime Time?)
23	Evtol Insights, 2020 (Podcast: Ep. 10 – Wisk's Chief Marketing Officer Becky Tanner)	61	NASA, 2021 (Official Website)
24	Evtol Insights, 2020 (Podcast: Ep. 11 – Felipe Varon, CEO and Founder of Varon Vehicles)	62	NASA, 2021 (Report: NASA Electric Vertical Takeoff and Landing (eVTOL) Aircraft Technology for Public Services)
25	Evtol Insights, 2020 (Podcast: Ep. 12 - George E. Bye - Bye Aerospace)	63	Nissan, 2022 (Official Website)
26	Evtol Insights, 2020 (Podcast: Ep. 14 - Christoph Fraundorfer CEO of Fraundorfer Aeronautics)	64	Porsche, 2022 (Official Website)
27	Evtol Insights, 2020 (Podcast: Ep. 15 - Co-Founder and CEO of Airflow.aero, Marc Ausman)	65	PWC, 2018 (Report: Industrial Mobility and Manufacturing)
28	Evtol Insights, 2020 (Podcast: Ep. 16 – Flock's Sales and Marketing Leade, Sam Golden)	66	Roland Berger, 2018 (Report: Urban air Transpor – The rise of a new mode of Transportation)
29	Evtol Insights, 2020 (Podcast: Ep. 17 - Trancend Air's CEO Greg Bruell and COO Peter Schmidt)	67	Rolls-Royce Holdings, 2022 (Official Website)
30	Evtol Insights, 2020 (Podcast: Ep. 19 – Neil Cloughley, MD of Faradair Aerospace)	68	Tencent, 2022 (Official Website)
31	Evtol Insights, 2020 (Podcast: Ep. 2 – Skyports' Duncan Walker, founder and CEO)	69	Tesla, 2022 (Official Website)
32	Evtol Insights, 2020 (Podcast: Ep. 21 – Darrell Swanson of Swanson Aviaton Consultansy and Julian Carlson of Pascall + Watson)	70	The Business Research Company, 2022 (Report: eVTOL Aircraft Global Market Report 2022)
33	Evtol Insights, 2020 (Podcast: Ep. 23 – Thomas Pfammatter and Jasmine Kent of Dufour Aerospace)	71	Toyota Motor, 2022 (Official Website)
34	Evtol Insights, 2020 (Podcast: Ep. 26 – Marco Pugliese, Head of Institucional Relations at Walle Mobility)	72	Uber Elevate, 2016 (Report: Fast-Forwarding to a Future of On-Demand Urban Air Transportation)
35	Evtol Insights, 2020 (Podcast: Ep. 31 – Yolanka Wulff, Co-Executive Director of the Community Air Mobility Initiative (CAMI))	73	Uber Elevate, 2022 (Official Website)
36	Evtol Insights, 2020 (Podcast: Ep. 7 - Ed De Reyes, CEO of Sabrewing Aircraft)	74	UKRI, 2021 (Report: Future Flight Vision and Roadmap August 2021)
37	Evtol Insights, 2020 (Podcast: Ep. 8 – Vertical Aerospace CEO Michael Cervenka)	75	Volkswagen, 2022 (Official Website)
38	Evtol Insights, 2020 (Podcast: Ep. 9 – Dr. Yoeli of Urban Aeronautics)	76	Volocopter, 2022 (Official Website)

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