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BRAZILIAN CENTER FOR
INTERNATIONAL RELATIONS

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ENERGY PROGRAM

MOBILITY OF THE FUTURE
Climate change and new technologies

About CEBRI

The Brazilian Center for International Relations (CEBRI) is an independent think tank that contributes to building an international agenda for Brazil. For over twenty years, the institution has engaged in promoting a pluralistic and proposal-oriented debate on the international landscape and Brazilian foreign policy.

In its activities, CEBRI prioritizes themes with the greatest potential to leverage the country's international insertion into the global economy, proposing pragmatic solutions for the formulation of public policies.

It is a non-profit institution, headquartered in Rio de Janeiro and internationally recognized. Today, its circa 100 associates represent diverse interests and economic sectors and mobilize a worldwide network of professionals and organizations. Moreover, CEBRI has an active Board of Trustees composed of prominent members of Brazilian society.

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CATAVENTO

Partnership:

Kingdom of the Netherlands

ENERGY PROGRAM

This Program encourages the discussion on questions related to the Energy and Oil & Gas (O&G) sectors and their global trends.

Its focus has been to investigate topics with the potential to enhance the insertion of the Brazilian industry into global chains and influence the formulation of public policies that create a competitive and attractive investment environment, such as technological innovations and their impacts on the sector's competitiveness; the geopolitical impacts of the increasing relevance of renewable sources in the global energy mix; the identification of anchor sectors for fossil fuel demand in the long term; changes in the sector's regulations, etc.

TRUSTEE

Jorge Camargo

Former president of the Brazilian Petroleum, Gas and Biofuels Institute (IBP) and senior advisor at McKinsey & Company. Previously, he worked for Statoil, as senior vice-president in Norway and later as president of Statoil in Brazil. He is also a member of the Board of Directors at Ultrapar Group and at Prumo Logistics.

SENIOR FELLOW

Clarissa Lins

Clarissa is the founding partner of Catavento, a consultancy on strategy and sustainability. Since November 2019, she is the President of the Brazilian Petroleum Institute (IBP). Clarissa is also a member of Suzano's Sustainability Committee and the Global Future Council on the Future of Energy at the World Economic Forum. She has served on Petrobras' Board of Directors, the Sustainability Committee of Vale's Board of Directors, and Shell's External Review Committee. Clarissa has a bachelor's and a master's degree in economics from PUC-Rio.

EXECUTIVE DIRECTOR

Julia Dias Leite

She is CEBRI's Executive Director since 2015. Previously, she worked for 10 years at the Brazil-China Business Council, where she occupied the position of Executive Secretary. Recently, she was chosen by the U.S. State Department to participate in the Young World Leaders program.

The first event organized by CEBRI's Energy Program in 2020 was held on February 13th and leveraged on the support of the Dutch Consulate in Rio de Janeiro. The event aimed to analyze how technologies, integrated planning, and connected public transport can reshape the transport sector in the context of climate change. It was structured in two different panels, the first – "Climate change impacts and the role of new technologies in human mobility" – and the second one – "Mobility systems - aiming for efficiency and sustainability" – focusing on different transport alternatives, such as individual, public, and air transportation.

The event was moderated by Jorge Camargo, Vice Chairman of CEBRI's Board of Trustees and coordinator of the Energy Program, and Clarissa Lins, CEBRI's Senior Fellow and Catavento's founding partner. The event benefitted from insights presented by Clarisse Linke, Country Director at the Institute for Transportation and Development Policy (ITDP – Brasil), Sergio Jacobsen, Senior Vice-President of Siemens Brazil's Operational Smart Infrastructure, Suzana Kahn Ribeiro, Professor at COPPE/UFRJ, Seth Van Straten, Commercial Director for South America at Air France-KLM Group, and Antonio Simões, Energy Executive Director at Raízen.

Disclaimer: This paper consolidates the content presented by each participant, the debate that followed and additional insights provided by Catavento. As it occurred before the COVID-19 pandemic, there is no insight related to the current crisis.

Table of Contents

PANELISTS 07

EXECUTIVE SUMMARY 10

1. TRANSPORT SECTOR: EMISSIONS PROFILE AND FOSSIL FUELS 12

1.1. Improve: technological development towards an efficient and more sustainable mobility system 16

1.2. Avoid and shift: integrated planning towards efficient mobility systems 19

2. BRAZIL: OVERALL PANORAMA AND PARTICULARITIES 21

2.1. Improve: ethanol and global trends in Brazil 22

2.2. Avoid and shift: public policies aiming at sustainable mobility 25

3. FINAL REMARKS 28

4. REFERENCES 29

PANELISTS

Clarisse Linke

Country Director at Institute for Transportation and Development Policy (ITDP - Brazil)

Clarisse Cunha Linke is a Brazilian who has been involved in planning and implementing social policies and programs since 2001, with experience in Brazil, Mozambique, and Namibia. Clarisse joined ITDP Brazil in 2012. In 2019, she was recognized as a "Remarkable Women in Transport" by the Transformative Urban Mobility Initiative (TUMI).

From 2006-2011, she was a Director at the Bicycling Empowerment Network Namibia (BEN Namibia), where she played a key role in the expansion of BEN Namibia's activities, helping it develop the biggest community-based enterprise bicycle distribution network in sub-Saharan Africa. In 2010, she was awarded by Ashoka Changemakers in the "Women, Tools, and Technology" Challenge for the work done in Namibia with women. From 2016-18 she taught "NGO Management" at the Institute of Economics in the Rio de Janeiro Federal University (UFRJ). From 2017-2019 she was a Board Member of the Sustainable Low Carbon Transport Network (SLoCaT). Since 2018, she is a member of the Global Future Council on Mobility, from the World Economic Forum.

She holds a Masters in Social Policy, NGOs, and Development from the London School of Economics and Political Science (LSE), where she received the "Titmuss Examination Prize" in 2005.

Sergio Jacobsen

Senior Vice President of Siemens Brazil's Operational Smart Infrastructure

Sergio Jacobsen has been Senior Vice President of Siemens Brazil's Operational Smart Infrastructure since April 2019, covering the areas of medium and low voltage solutions and products, control products for industrial automation, building automation, generation and storage of distributed energy and solutions for electro mobility.

He is also responsible for the Digital Grid business unit, which encompasses the entire automation and digitization portfolio of the Siemens energy area, as well as two of Siemens eight R&D centers in Brazil and a global competence center for non-technical losses.

Sergio has been working at Siemens since 2001, has held various positions within the Smart Grids area and has been CEO of Senergy since its acquisition.

He has gained experience in projects with the main Brazilian dealers and is in constant contact with specialists from the local competence centers and around the world.

Sergio holds a bachelor's degree in Electrical Engineering at Mackenzie University, a pos graduation in Administration at FIA – Institute of Administration Foundation and an executive MBA at ESMT Berlin – European School of Management and Technology.

Suzana Kahn

Professor at COPPE (UFRJ)

Suzana Kahn Ribeiro is full Professor at COPPE / UFRJ. She is researcher at the areas of renewable energy, climate change, urban mitigation alternatives and sustainable mobility. She is coordinator of the UFRJ Green Fund and "ad hoc" consultant for the Brazilian Research and Development Council.

Suzana is the Lead Coordinator and author of The Intergovernmental Panel on Climate Change (IPCC). She is also Member of the Council of Museu do Amanhã, President of the Deliberative Council of BVRio, Member of the Brazilian Business Council for Sustainable Development (CEBDS).

She was Sub Secretary of Green Economy of Rio de Janeiro State Government from 2010-2013 and she also worked at the Brazilian Federal Government as the National Secretary of Climate Change at the Ministry of Environment from 2008-2010.

From 2008 to 2015, she took part of IPCC - Intergovernamental Panel on Climate Change board, as Vice President of Working Group III. She has published several papers and theses in the area of transport planning, sustainable mobility, energy planning, biofuels, environment and climate change. More recently she has been involved in the topic of sustainable and smart cities. As president of Scientific Committee of Brazilian Panel on Climate Change she has organized 3 assessment report on climate change and 3 special reports.

Graduated in Mechanical Engineering, MSc in Energy Planning Program and DSc in Industrial Engineering from the Federal University of Rio de Janeiro (1995).

Seth Van Straten

Commercial Director for South America at Air France-KLM Group

Seth van Straten is the Commercial Director for South America, which includes Argentina, Brazil, Bolivia, Chile, Paraguay and Uruguay, based in São Paulo. Seth joined the Air France-KLM Group in 2011, having built his career in the commercial domain.

Starting his career within the pricing & revenue management domain in Amsterdam, Seth has also worked in Shanghai as a consultant for a partner airline. In 2015, this time in Paris, he became director for the Air France-KLM Group.

Straten holds a master's degree in Industrial Engineering and Management from Twente University (2008) as well as a master's law degree from the University of Amsterdam (2011).

Antônio Simões R. Junior

Energy Executive Director at Raízen

Antônio Simôes R. Junior currently holds the position of Energy Executive Director at Raízen looking after biomass, generation, trading and marketing of renewable energy and related businesses.

Previously he was the Supply Chain and Logistics Director for Raízen in Brazil (2015- 2019) and before that, was responsible for starting up and developing the company's global ethanol trading based in Geneva where he was the Global Trading Director, (2011- 2015). He also serves as an alternate member of the board of Logum (Ethanol Pipeline System) and as a member of the executive board of some of Raízen's joint ventures. Between 1997 and 2010 he held several positions in Trading, Supply, and Logistics at Shell, in Rio de Janeiro, London, and Dubai.

He is a Production Engineer graduated from Universidade Federal Fluminense (UFF), with an MBA in marketing from CEFET-RJ.

MODERATORS

Jorge Camargo

Vice Chairman of CEBRI's Board of Trustees

Jorge Camargo is Vice Chairman of CEBRI's Board of Trustees and the coordinator of the Energy Program. Senior energy expert, Camargo spent his career in the O&G industry. He currently serves on the Board of Directors of Ultrapar Group and Prumo Logística. Camargo was the President of the oil and gas industry association - Brazilian Petroleum Institute (IBP) from 2016 to 2018.

He made a successful career of almost 30 years at Petrobras, serving at its Executive Board as International Director (2000-2003). He also worked for Equinor as Senior vice-president in Norway and later as the first CEO of Equinor in Brazil. Camargo is a geologist by training holding a degree from the University of Brasilia (UnB) and a Masters in Geophysics from the University of Texas at Austin.

Clarissa Lins

Senior Fellow of CEBRI's Energy Program and founding partner at Catavento

Clarissa is Senior Fellow at CEBRI's Energy Program and the founding partner of Catavento, a consultancy on strategy and sustainability. Since November 2019, Clarissa is the President of the Brazilian Petroleum Institute (IBP).

Clarissa is also a member of Suzano's Sustainability Committee and the Global Future Council on the Future of Energy at the World Economic Forum. She served on Petrobras' Board of Directors (2018 to 2019), chaired the HSE Committee and was a member of the Audit Committee. She also served on the Sustainability Committee of Vale's Board of Directors (2017 to 2019) and on Shell's External Review Committee (2012 to 2015).

Clarissa is an economist by training and holds her bachelor's and master's degrees from the Catholic University of Rio de Janeiro PUC Rio.

EXECUTIVE SUMMARY

1. **The transport sector is critical in the context of climate change.** The current mobility model adopted in most countries mainly relies on individual internal combustion vehicles. Today, there are over 1.1 billion passenger cars on the road, a 50% increase compared with 2010.

2. **This context tends to be aggravated by the fast pace at which the world's population has been growing and by the accelerated process of urbanization.** By 2040, the global population is expected to grow by almost 2 billion people, of which 1.8 billion will live in urban areas.[1]

3. **On the other hand, the transport sector is being reshaped by new technologies and consumption patterns.** Automated driving, shared mobility, and vehicle electrification will dramatically impact road transport over the coming years, with major implications to individual mobility. According to IEA, the global electric vehicle fleet could reach 250 million by 2030, from 5 million today.[2]

4. However, further transformations are necessary to promote a sustainable, accessible, and affordable mobility system. **The avoid, shift, and improve strategy[3] could reduce GHG emissions, energy consumption, and congestions.** These strategies envision city areas closely connected, efficient individual trips, and well-developed public transportation systems.

5. **Climate change and extreme weather events are also impacting the Brazilian transport sector, especially for those living in low income regions.** In 2020, the metropolitan area of São Paulo was severely affected by continuous rainfalls. February was the rainiest month in more than 77 years, leading to at least 10 casualties, power supply interruption and infrastructure damage[4]. However, some particularities must be taken into consideration when analyzing the Brazilian context.

6. **Ethanol accounts for 20% of the Brazilian transport sector's energy demand, behind diesel oil (44%) and gasoline (26%).** Through the RenovaBio Program, the Brazilian government aims to promote the expansion of ethanol production from its

1. World Bank. Population estimates and projections. 2017
2. IEA. Global EV Outlook. 2019
3. ITDP. Mobilidade de baixo carbono. 2019; GIZ. Sustainable urban transport. 2019
4. Accuweather. Heavy rain, landslides leave several dead on coast of São Paulo, Brazil. 2020 – Available at: <https://www.wnep.com/article/weather/accuweather/heavy-rain-landslides-leave-several-dead-on-coast-of-sao-paulo-brazil/607-86ac3bd4-661a-4624-828a-4292b71588bf>

current level of 30 billion liters to around 50 billion liters by 2030, of which 90% will be destined to the transport sector.[5]

7. **On the other hand, the ethanol relevance does not seem like a reason to believe that the Brazilian transport sector would be immune to global mobility trends, such as vehicle electrification.** Recent technological developments coupled with the size of the country's domestic market will probably make electric vehicles an attractive option in the medium-term.

8. **Lastly, inefficiencies from the Brazilian transportation sector must be addressed through an integrated planning, that takes into consideration the challenges towards a sustainable mobility system.** Some recent projects, such as the bus rapid transit (BRT), promote significant improvements to the traffic flow. However, further actions aligned with effective public policies must be implemented.

5. EPE. Plano Decenal de Energia 2029. 2020; IEA. Bioenergy Task 39. 2019

1. TRANSPORT SECTOR: EMISSIONS PROFILE AND FOSSIL FUELS

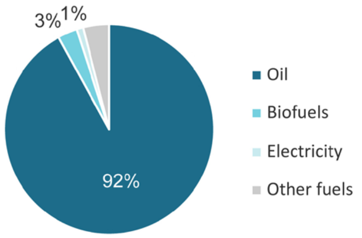
Climate change is already reshaping the global scenario. Global temperatures have been increasing at a rapid pace. For example, temperatures on the Antarctic continent have risen by almost 3°C over the past 50 years, and near 87% of its glaciers have retreated in the same period[6]. At the same time, extreme weather events, such as storms, floods, and heat wave, are becoming more frequent.

In 2018, total economic losses from natural disasters amounted to approximately US$ 165 billion[7]. Asia accounted for almost 1/3 of all events worldwide, totaling 104 disasters. In Brazil, for example, the frequency of natural disasters increased by 270% between 2001 and 2010 when compared to previous decades[8].

In this context, climate events have been severely impacting transport systems and increasing the frequency of service interruptions. This scenario has direct implications on the mobility of inhabitants and on the quality of life. The most affected are usually among those living in poor regions, who rely mostly on public transportation and are exposed to longer travel distances. Nonetheless, the transport sector may have a prominent role in reducing global emissions and thus reducing physical risks due to climate change.

The sector accounts for 24% of direct global CO_2 emissions by energy use (second-largest emitter, behind electricity generation)[9]. Road vehicles, such as cars, trucks, and buses, account for nearly 75% of transport CO_2 emissions[10], followed by shipping (11%) and aviation (11%). This emission profile is associated with the sector's energy demand, which is highly dependent on fossil sources. According to IEA[11], oil represents almost 92% of the transport's total energy demand, equivalent to 2.629 Mtoe in 2018.

Figure 1. **Energy demand – transport sector (2018)** (%)



Source: IEA. World Energy Outlook. 2019

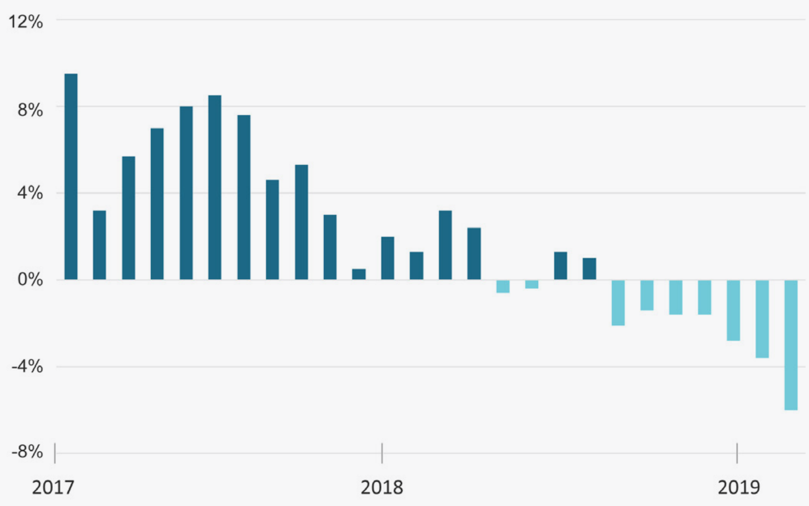
6. UN World Meteorological Organization. New record for Antarctic continent reported. 2020
7. WEF. How cities can become more resilient to climate change. 2019
8. ITDP. Transporte y desarollo en America Latina. 2019
9. IEA. CO_2 emissions from fuel combustion. 2017
10. IEA. Tracking transport. 2019
11. IEA. World Energy Outlook. 2019

The aviation industry and climate change

Aviation companies are under increased pressure to address rising global awareness towards the climate urgency, its risks to businesses, and to society's well-being. Recently, climate activists helped to popularize the "flight-shaming" movement across Europe[12].

The movement aims to promote less carbon emitting modes of transportation, in order to replace air travel. In Sweden, the birthplace of this movement, air ridership already is declining, even though flight-shaming cannot be attributed as the single cause [Fig. 03][13]. In parallel, passenger numbers reached a record high at the national state train operator. Companies such as the Dutch airline KLM have jumped into the movement and encouraged its customers to, whenever possible, take trains or engage in video calls instead of flying.

Figure 2. **Change in total passengers month on month - Swedish airports** (%)



Source: Bloomberg. As 'Flying Shame' Grips Sweden, SAS Ups Stakes in Climate Battle. 2019 – Available at: <https://www.bloomberg.com/news/articles/2019-04-14/as-flying-shame-grips-sweden-sas-ups-stakes-in-climate-battle>

Although consumer awareness may be increasing in some regions, the aviation industry is still responsible for about 2% of global CO_2 emissions. If it were a country, it would rank among the global top 10 emitters[14]. The International Air Transport Authority (IATA)

12. Forbes. Can The Airline Industry Survive Climate Change? 2020 – Available at: < https://www.forbes.com/sites/andystone/2019/12/10/can-the-airline-industry-survive-climate-change/#2775810b708e>
13. Bloomberg. As 'Flying Shame' Grips Sweden, SAS Ups Stakes in Climate Battle. 2019 – Available at: < https://www.bloomberg.com/news/articles/2019-04-14/as-flying-shame-grips-sweden-sas-ups-stakes-in-climate-battle>
14. IATA. Climate Change. 2020 – Available at: <https://www.iata.org/en/policy/environment/climate-change/>

expects annual passenger numbers to double by 2037, significantly increasing the sector's carbon emissions[15].

In 2009, IATA set a goal for carbon-neutral growth from 2020 onwards and established an ambition to reduce net aviation carbon emissions in 50% by 2050[16]. Regardless, between 2013 and 2018 the global CO_2 emissions from commercial flights rose 70% faster than previously predicted[17].

Given the scale of this challenge, the International Civil Aviation Organization (ICAO) aims to improve aircraft technology, enhance efficient operations, and reduce emissions through its Carbon Offsetting and Reduction Scheme for International Aviation program (CORSIA)[18]. With these initiatives, CORSIA should be able to mitigate around 2.5 billion tonnes of CO_2 by 2035.

In addition, replacing fossil fuels with sustainable biojet fuels can be an important tool to reduce the industry's carbon footprint. **Biojet fuels will be essential to decarbonize the industry, since existing technologies do not allow it to be fully electrified at a scale and competitive costs. Projections indicate that biojet fuels could reduce CO_2 emissions by up to 80% when compared to fossil fuels**[19]. However, these alternative fuels are not yet cost competitive and remain significantly expensive. Therefore, increasing low-carbon fuel shares in the aviation fuel mix will demand considerable R&D investments and upscaling of more mature technologies.

In this sense, the aviation industry is considered one of the most challenging transport subsectors to be decarbonized[20]. Low and no-emissions airplanes able to carry hundreds of passengers will not be a reality until decades into the future.

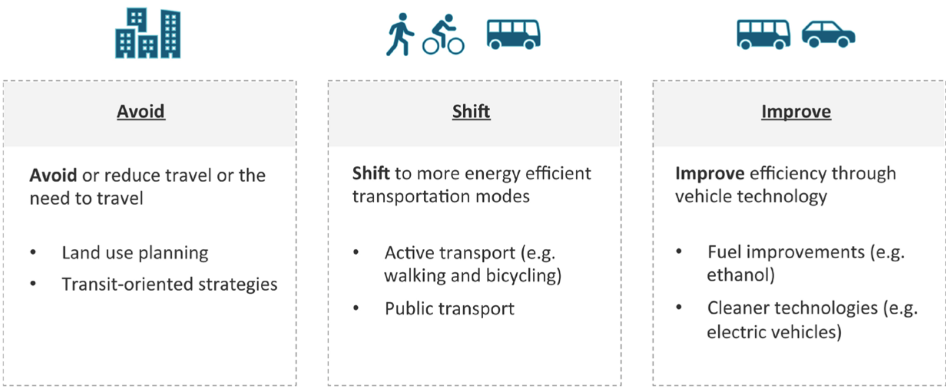
15. IATA. Climate Change. 2020 – Available at: <https://www.iata.org/en/policy/environment/climate-change/>
16. IATA. Climate Change. 2020 – Available at: <https://www.iata.org/en/policy/environment/climate-change/>
17. IRENA. Discussions on Sustainable Aviation Take Place in Abu Dhabi. 2020 – Available at: <irena.org/newsroom/articles/2020/Feb/Discussions-on-Sustainable-Aviation-Take-Place-in-Abu-Dhab>
18. IRENA. Discussions on Sustainable Aviation Take Place in Abu Dhabi. 2020 – Available at: <irena.org/newsroom/articles/2020/Feb/Discussions-on-Sustainable-Aviation-Take-Place-in-Abu-Dhab>
19. KLM. Carbon footprint reduction. 2020 – Available at: <https://klmtakescare.com/en/content/carbon-footprint-reduction>
20. IEA. Tracking transport. 2020

As for road transport, the mobility model currently adopted in most countries is characterized by individual internal combustion engines. There are over 1.1 billion passenger cars on the road today, roughly 50% more than a decade ago. Trends such as population growth and urbanization are expected to accelerate this trajectory in the coming years. According to the United Nations[21], the world population will increase from 7.8 billion in 2020 to 9.8 billion by 2050. At the same time, as much as 68% of the population will live in urban areas by the same year – up from 55% today[22].

In addition, developing economies are becoming wealthier, resulting in higher incomes for the middle class which will likely yield higher vehicle ownership[23]. The level of private cars in countries such as India, China, and Brazil is still far below that in more advanced economies. Major cities in developing economies already face severe congestions and, therefore, an increase in their populational density will represent an additional pressure on current mobility systems and lead to higher emissions, aggravation in local pollution, and lower quality of life for the citizens.

In this sense, the transport sector must adapt in order to reduce its emissions, as well as mitigate the potential impacts of climate change events. Experts point to a need to rethink the current mobility system through a different approach, focusing on people and their mobility needs instead of individual vehicle infrastructure. The ASI strategy (Avoid, Shift, and Improve) is seen as the most effective towards a more reliable, integrated, and flexible mobility, with lower GHG emissions and energy consumption[24] [Fig. 01].

Figure 3. **Avoid – Shift – Improve strategies**



Sources: ITDP. Mobilidade de baixo carbono. 2019; GIZ. Sustainable urban transport. 2019

21. United Nations. World population. 2017
22. MIT. Insights into the future of mobility. 2019
23. MIT. Insights into the future of mobility. 2019; IEA. World Energy Outlook. 2019
24. ITDP. Mobilidade de baixo carbono. 2019

The "avoid" pillar refers to the need to improve transport and urban land use planning through a transit-oriented development approach, reducing travel distances. Therefore, different city areas must become closely connected, such as residential, work and leisure districts.

The "shift" pillar aims to improve individual trip efficiency, changing energy consumption and polluting modes (e.g. individual combustion cars) towards more environmentally friendly modes. In particular, there are two crucial transport modes in this sense: the active transport, such as walking and cycling, and the public transport, such as bus and rail.

The "improve" pillar is considered the most common and is usually in the spotlight of most adaptation strategies. It focuses on vehicle and fuel efficiency, and it is highly associated with technological development and operational optimization[25]. In this sense, different actors, mainly government, must encourage development plans that avoid the need to travel long distances, shift trips to lower carbon modes, and improve the current mobility system energy efficiency[26].

1.1. Improve: technological development towards an efficient and more sustainable mobility system

Mobility trends are being boosted by technological development such as **automated driving, shared mobility, and vehicle electrification**. These trends are expected to dramatically impact road transport over the coming years, with major implications to individual mobility[27].

Rapid advances in connectivity, sensing technologies, and artificial intelligence are promoting significant developments in **autonomous vehicle technologies**. The technology is expected to reduce road safety concerns, as well as increase access to mobility services[28]. Driving accidents are one of the top 10 global death causes, in which nearly 95% of these accidents are caused by human error. In addition, autonomous vehicles may turn driving time into free time, increasing commuting convenience.

In 2019, Waymo launched its self-driving car service, Waymo One[29], while major automakers, such as Ford[30] and General Motors[31], have announced plans to introduce autonomous vehicles in the coming years. However, autonomous technologies are not mature enough, nor close to widespread deployment[32]. New regulations will be needed to address current challenges, such as liability and data protection.

25. GIZ. Sustainable Urban Transport. 2019
26. ITDP. The Paris Agreement: What is right and what is next. 2019; GIZ. Sustainable urban transport. 2019
27. IEA. Commentary: Shared, automated… and electric? 2019
28. McKinsey. The future(s) of mobility: How cities can benefit. 2018
29. Waymo. Technology. 2019 – Available at: <https://waymo.com/static/images/technology/technology_lidar.jpg>
30. Ford. Autonomous 2021. 2019 – Available at: <https://corporate.ford.com/articles/products/autonomous-2021.html>
31. GM. Autonomous and electric. 2019 – Available at: <https://www.gm.com/masthead-story/electric-vehicles-AV-EV.html>
32. MIT. Insights into future mobility. 2019

At the same time, new technologies, especially digitalization, are also enabling the development of **shared mobility.** Car sharing fleets tend to have shorter trip distance profiles on a short-term basis, being characterized as one of the most convenient modes of transport. These services have grown rapidly over the past few years. For example, Uber, created in 2013 and currently the most popular ride-hailing service, is now operating in 900 cities worldwide, with more than 5 million drivers and 22 million clients[33].

Those services are being boosted by changing consumer preferences, especially from younger generations. They are usually more likely to embrace the sharing and digital economy. Recent studies are indicating early signs that the importance of private-car ownership is declining, whilst the preference for shared mobility services is increasing. In the United States, for example, the share of young people (16 to 24 years) holding driver's license dropped from 76% to 71% between 2000 and 2013[34].

Additionally, the **electrification trend** is also expanding at a rapid pace. According to the IEA, the global electric car fleet exceeded 5.1 million units in 2018, up 2 million from the previous year and almost doubled the number of new electric car sales[35]. China holds around 45% of the global electric car fleet, the world's largest electric vehicle market followed by Europe (24%) and United States (22%)[36]. The Asian country is also leading the electrification of buses, accounting for 99% of the operational fleet worldwide[37]. The city of Shenzhen, for example, became the global model when it transitioned its entire bus fleet to electric within only a few years[38].

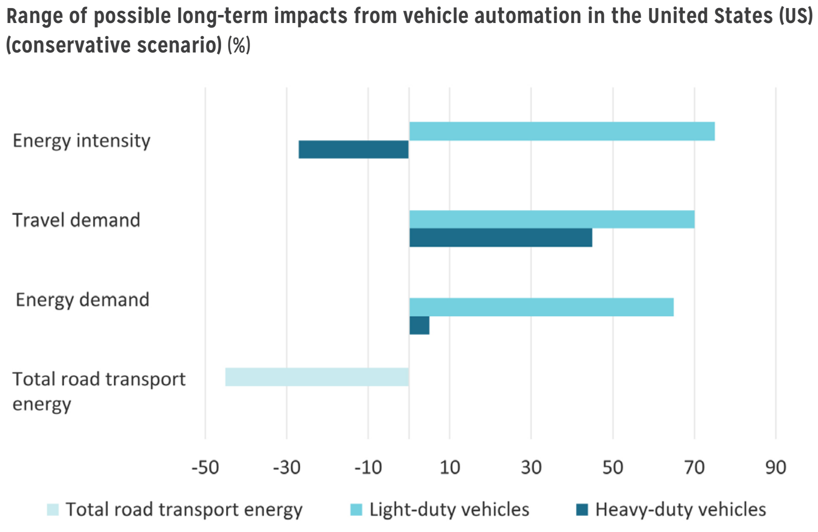
Technological developments and new investments are reducing costs and promoting expressive product improvements. Battery prices, which are responsible for nearly 45% of the total vehicle cost, continue to fall. Between 2010 and 2018, the average lithium-ion pack price experienced an 85% price reduction. As a result, projections indicate that a price parity between electric and internal combustion vehicles could take place by 2025 in different segments and geographies[39].

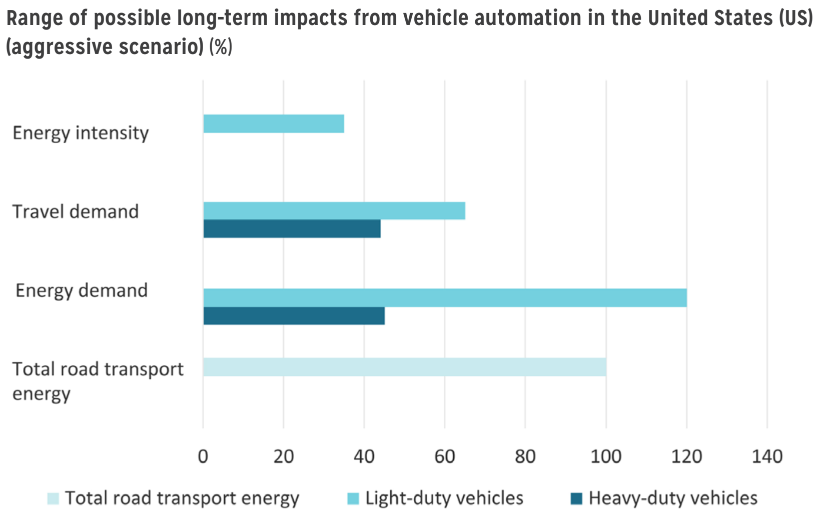
Moreover, electric vehicles are on average less carbon intensive than conventional internal combustion engine (ICE) vehicles. The extent of this advantage, however, ultimately depends on the country's power mix: CO_2 emissions savings are significantly higher in countries where the power generation relies on renewable sources. Therefore, in a global scenario of power generation decarbonization, there is a clear opportunity for electric vehicles to propel the transition to a low carbon economy.

33. Uber. Fatos e Dados sobre a Uber. 2019
34. McKinsey. Disruptive trends that will transform the auto industry. 2019
35. IEA. Global EV Outlook. 2019
36. IEA. Global EV Outlook. 2019
37. IEA. Tracking Transport. 2019 – Available at: <https://www.iea.org/reports/tracking-transport-2019/electric-vehicles>
38. IEA. Tracking Transport. 2019 – Available at: <https://www.iea.org/reports/tracking-transport-2019/electric-vehicles>
39. BNEF. Electric Vehicle Outlook. 2019

However, differently from the electrification trend, automation and shared mobility may lead to a net increase in energy consumption and emissions [Fig.02]. Both trends could boost higher overall vehicle mileage as people take advantage of their convenience by making more daily trips. Meanwhile, these technologies may reduce public transport utilization, walking, and cycling, leading to congestions in urban areas[40].

Figure 4. **Autonomous technology impact on energy demand – United States (US)**





Source: IEA. Do automated cars dream of electric sharing? 2019

40. McKinsey. The trends transforming mobility's future. 2019

For example, in the United States, a typical ride-hailing trip, currently the most common type of shared mobility, is already 69% more polluting on average than the traditional trips they replace[41], and there are two primary reasons for that. Firstly, due to a phenomenon known as deadheading, which is associated with the miles driven without any passenger in the car. It occurs frequently between the dropping off and the picking up of new passengers. The second reason is that ride-hailing is not only replacing private cars, but also increasing the number of car trips on the road.

In this context, electrification could help to reduce the energy use and emissions from autonomous and shared vehicles, since it is more energy and carbon efficient. The combination of these trends will promote the development of on-demand autonomous electric vehicles, a new business model called transport-as-a-service (TaaS) or mobility-as-a-service (MaaS)[42]. The adoption of MaaS will have significant implications in the current mobility systems. Due to its potential to the sector's emission reduction, it may be considered one relevant "improve" strategy for the near future.

With high utilization rates, commercial fleets such as those used on ride-hailing services will benefit from powertrains with low operational costs and higher efficiencies like those in electric vehicles (EVs). Electric vehicles have on average 80% less moving and wearing parts than conventional internal combustion vehicles, reducing its mechanical complexity and maintenance costs[43].

Automated driving technologies may be easier to implement in EVs due to the greater number of drive-by-wire components. While the outlook for electrification of AVs seems promising, commercial services will demand greater utilization and range, requiring larger and more expensive battery packs or more frequent recharging. On-board computers and electronics may also demand significant electricity, reducing the range of an electric autonomous vehicle.

1.2. Avoid and shift: integrated planning towards efficient mobility systems

Technological trends have the potential to help the transport system to fulfill its role in reducing emissions. However, further transformations are necessary to achieve global climate goals[44]. According to some experts, leaders should develop plans that avoid the need to travel distances and shift trips to low carbon modes[45].

41. Union of Concerned Scientists. Ride-hailing's climate risks. 2020
42. MIT. Rethink.X Transportation 2020-2030. 2017
43. UBS. Disruption ahead. 2017
44. ITDP. The Paris Agreement: What's Right and What's Next. 2015
45. ITDP. The Paris Agreement: What's Right and What's Next. 2015

Firstly, it is necessary to plan dense scale cities that provide space for people's mobility, and not only vehicles. **Planning dense cities with closely connected residential, work, and leisure areas will improve the access to goods, services, and public transport, ensure a better use of public spaces and, at the same time, reduce travel distances**[46].

This strategy must also promote the development of residential and commercial uses around high capacity mobility alternatives, such as subway and railway stations. **By developing transit-oriented strategies, cities will enhance transport efficiency, reduce commuting time, and ensure better land value capture around transit**[47].

In addition, shifting to walking, cycling, and public transportation, instead of individual vehicles, will improve mobility, reducing the sector's energy consumption and local pollution. Active transport, such as walking and cycling, is considered the most effective environmental option towards sustainable mobility[48]. Therefore, cities must develop complete urban cycling networks and pedestrian zones, limiting road space for cars and other vehicles[49].

Besides being low carbon options, walking and cycling are cheap and flexible, allowing the low-income population to access education, healthcare, and other services. Cycling, for example, has an annual cost range from US$ 200 to US$ 340, while costs involved in driving a car vary between US$ 2,800 and US$ 9,600[50]. Today, cycling still represents approximately 7% of urban trips. A shift to 23%, for example, could avoid 300 MtCO2eq of emissions worldwide, as well as save cities up to US$ 25 trillion over the next 35 years[51] on infrastructure costs.

At the same time, fast, reliable, and affordable high-capacity public transport reduces the need for private car ownership and addresses socioeconomic inequality and climate change. For instance, well-integrated public transportation helps eliminate traffic congestion, local pollution, and connects low-income communities to different regions[52]. According to McKinsey, cities where people are most satisfied with mobility systems are those committed with efficient public transport and with some level of restriction on car ownership[53].

Therefore, effective transportation strategies could also help cities and governments to improve not only the environment, but also the population's quality of life[54].

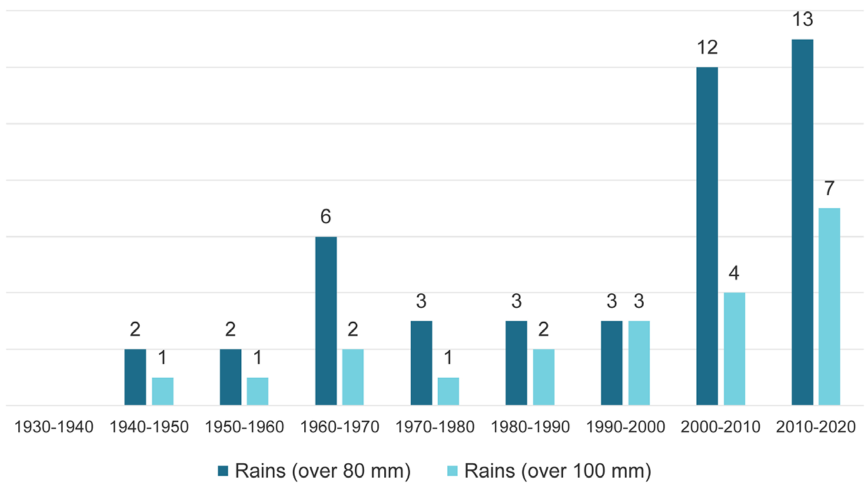
46. GIZ. Sustainable Urban Transport. 2019
47. SUTP. Developing transit-oriented cities. 2020 – Available at: < https://www.sutp.org/principles/developing-transit-oriented-cities/>
48. ITDP. A Global High Shift Cycling Scenario. 2016
49. SUTP. Sustainable Urban Transport Project. 2019 – Available at: < https://www.sutp.org/publications/inua-2-solution-cycling/>
50. UN. Cycling better mode of transport. 2020 – Available at: < https://www.unenvironment.org/news-and-stories/story/cycling-better-mode-transport>
51. ITDP. The Paris Agreement: What's Right and What's Next. 2015
52. ITDP. Public Transport. 2018
53. McKinsey. Urban transportation systems. 2019
54. ITDP. The Paris Agreement: What's Right and What's Next. 2015

2. BRAZIL: OVERALL PANORAMA AND PARTICULARITIES

Brazil and its transport sector are also being impacted by climate change. According to ITDP, the average temperature in the winter season has increased over 1°C since the second half of the last century[55]. Between 2001 and 2010, the frequency of extreme weather events has increased over 270% when compared to the previous decade[56]. Extreme weather events, including rainstorms, floods, and droughts, now occur more frequently than in the past, negatively affecting and interrupting transport services.

In 2020, the metropolitan area of São Paulo was severely affected by continuous rainfalls. The region is responsible for 17% of the country's GDP and is home to more than 22 million Brazilians. Recent studies show a significant increase in the total rainfall volume during the rainy season in the past seven decades [Fig. 04]. While there were practically no days with heavy rain (more than 50 mm) in the 1950s, these days have been occurring more than 20 times a year in the last decade[57]. February 2020, for example, was the rainiest month for São Paulo in over 77 years, leading to at least 10 casualties, power supply interruption and infrastructure damage[58].

Figure 5. **Heavy rains frequency – Metropolitan area of São Paulo** (# of days)



Source: New York Academy of Sciences. Trends in extreme rainfall and hydrogeometeorological disasters in the Metropolitan Area of São Paulo. 2020

55. ITDP. Transporte y desarollo en America Latina. 2019
56. ITDP. Transporte y desarollo en America Latina. 2019
57. New York Academy of Sciences. Trends in extreme rainfall and hydrogeometeorological disasters in the Metropolitan Area of São Paulo. 2020
58. Accuweather. Heavy rain, landslides leave several dead on coast of São Paulo, Brazil. 2020 – Available at: <https://www.wnep.com/article/weather/accuweather/heavy-rain-landslides-leave-several-dead-on-coast-of-sao-paulo-brazil/607-86ac3bd4-661a-4624-828a-4292b71588bf>

In this sense, extreme weather events are expected to increase in São Paulo and other cities around the world, intensified by higher GHG emissions and urbanization. At the same time, the impacts are exacerbated due to the high vulnerability of the urban population[59].

With extreme weather events, such as storms and floods, both the population and mobility systems are directly and indirectly affected. Differently from other countries, the Brazilian transportation sector, as well as its mobility systems, have some specificities and particularities that must be considered when analyzing the impact of climate change and mobility trends. For example, ethanol is very relevant for the Brazilian transportation sector, accounting for 20% of the sector's total energy demand, after diesel oil (44%) and gasoline (26%).

Since the 1970s, the Brazilian government made it mandatory to blend anhydrous ethanol with gasoline. Currently, the mandatory anhydrous content added to regular gasoline is 27%[60]. In addition, the national car industry developed in the 2000s flex fuel vehicles that can run on any proportion of gasoline and hydrous ethanol[61]. In 2017, 2.2 million new light-duty vehicles were licensed in Brazil, of which 89% were flex fuel. Today, they account for 74% of the total fleet and projections indicate to an even higher share by 2030 (90%)[62].

Although the Brazilian transportation sector is home to a relevant biofuel share due to ethanol usage in light-duty vehicles, it is still is the major contributor for GHG emissions by energy use. This can be partially explained by the significant use of fuel diesel on heavy vehicles in Brazil. In 2018, the transport sector accounted for over 47%, followed by the industrial (22%) and energy sectors (8%)[63]. The continuous urban development, as well as the lack of a well-integrated public transportation network, represent a significant challenge towards a sustainable and efficient mobility system in Brazil.

2.1. Improve: ethanol and global trends in Brazil

The share of renewable sources in the Brazilian vehicular mix can be partially explained by the promotion of public policies to encourage biofuels over the years, such as the National Alcohol Program (PROALCOOL), in the 1970s, and the insertion of flex fuel technology in 2000s.

In 2017, the Brazilian government established the National Biofuels Policy (RenovaBio) (Law No. 13,576). The Program aims to promote the expansion of the production and use of all biofuels in the country's energy matrix, as well as to help Brazil reach its commitment under the Paris Agreement. Through the Program, a market-based incentive

59. New York Academy of Sciences. Trends in extreme rainfall and hydrogeometeorological disasters in the Metropolitan Area of São Paulo. 2020
60. EPE. Plano Decenal de Energia 2029. 2020
61. IEA. Bioenergy Task 39. 2019
62. EPE. Energy demand of light-duty vehicle. 2018
63. EPE. Plano Decenal de Energia 2029. 2020

is developed by issuing GHG emissions certificates to biofuels producers according to their carbon efficiencies. These certificates, named CBios, will be traded in the country's stock market (B3) and purchased by fuel distributers[64].

The RenovaBio is based on an annual national decarbonization target for the fuel sector, that has been defined for a period of 10 years (2018-2028) by the Resolution CNPE n° 5, issued in June 2018. The emissions reduction target starts at 1% in 2019, gradually increasing up to 10.1% in 2028. This national target will be further broken down into individual mandatory goals for fuels distributers according to their market share[65]. In this sense, the CBio certificate value will be inversely proportional to the carbon intensity of the produced biofuel. According to EPE, under the RenovaBio, ethanol production could increase from its current level of 30 billion liters to around 50 billion liters by 2030, of which 90% will be destined to the transport sector.[66]

In addition to conventional biofuels, an increased production of advanced biofuels is expected to achieve further emissions reductions targets. Currently, Brazil has two commercial cellulosic ethanol plants. One of them belongs to GranBio, with the annual capacity of 82 million liters, and the other to Raízen, with the annual capacity of 42 million liters[67]. Through an enzymatic hydrolysis technology, both plants can increase their productions without increasing the area under cultivation.

GranBio was the pioneer with the first commercial-scale plant. The company expects to increase its production by 9 million liters by 2020 and 24 million liters by 2021, achieving production cost parity with conventional ethanol. Raízen, a joint venture between Shell and Cosan, started its commercial cellulosic ethanol production in 2014. By 2024, Raízen plans to build seven other plants, with the capacity to produce over one billion liters of cellulosic ethanol per year[68].

On the other hand, despite the perspectives for the ethanol industry, global mobility trends are also expected to influence the Brazilian transportation sector. The significant share of renewable sources in the country's vehicular mix reduces the pressure for public policies associated with electric mobility. However, technological development, which is delivering substantial cost cuts, will probably make electric vehicles an attractive option in the medium-term[69].

In addition, the relevance of the Brazilian domestic market – accounting for 52% of the GDP and 55% of the population in South America[70] – makes the country an attractive

64. IEA. Bioenergy Task 39. 2019
65. IEA. Bioenergy Task 39. 2019
66. EPE. Plano Decenal de Energia 2029. 2020; IEA. Bioenergy Task 39. 2019
67. IEA. Bioenergy Task 39. 2019
68. IEA. Bioenergy Task 39. 2019
69. CEBRI.CATAVENTO. Mobilidade elétrica: um novo cenário para o Brasil? 2019
70. World Bank. GDP data. 2019 – Available at: <https://data.worldbank.org/indicator/ny.gdp.mktp.cd>

investment option for global automakers. Major companies have already announced plans for vehicle electrification worldwide, including in Brazil.

In this sense, the penetration of electric vehicles in Brazil has the potential to reduce the sector's overall emissions. Differently from other countries, such as China and United States, Brazil has a power generation mix dominated by renewable energy sources – which represented 80% in 2018[71]. CO_2 emissions savings in electric cars depends on the power mix profile, being significantly higher in countries with a higher share of renewable energy sources. Recent studies estimate that electric vehicles could emit on average (25 gCO_2e/km) less GHG emissions than conventional internal combustion vehicles fueled with ethanol (45 gCO_2e/km) in Brazil on a well-to-wheel basis[72].

The deployment of electric vehicles in some countries occurred based on specific policy approaches. For example, in China, which is considered the front runner, policy developments include the restriction of investments in new internal combustion engines manufacturing plants, as well as regulations associated with fuel economy for passenger light-duty vehicles. Recently, Brazil has reduced the IPI tax (industrialized goods tax) from 25% to a range of 7-20% for full-electric and hybrid vehicles[73].

Henceforth, in the short term, some experts highlight that public policies could be more efficient on the deployment of electric buses in Brazil. Globally, electric urban buses are associated with rapid market uptake. There are some reasons behind this scenario, such as: their fixed routes with frequent stops, the placement of constant charging periods, and the local government's ambitions to reduce local air pollution[74]. Some Brazilian cities, such as São Paulo and Campinas, already have related public policies in place.

São Paulo, the largest city in South America, has a complex public transportation network, including over 14,000 diesel powered buses[75]. In 2009, the city conducted an analysis of bus routes that could be covered by electric models, and then held different pilot projects to evaluate their efficiency and performance. The city aims to replace diesel vehicles with lower emission technologies. In 2018, a Municipal Law (No. 16,802) established that vehicles for public transportation must reduce their CO_2 emissions by 50% within 10 years and by 100% within 20 years. In this sense, fuels such as ethanol or biogas are compliant with the 10-year target, but only electric vehicles meet the 20-year target for zero emissions. Therefore, local public policies associated with technological development have the potential to promote considerable growth for the electric bus market in Brazil[76].

71. EPE. Plano Decenal de Energia 2029
72. Nova Cana. A realidade do carro a etanol e o puro elétrico. 2017
73. Ministério da Economia. Roda 2030 – Mobilidade e Logística. 2019 – Available at: <http://www.mdic.gov.br/index.php/competitividade-industrial/setor-automotivo/rota2030>; Ministério da Economia. Legislação Rota 2030. 2018 – Available at: <http://www.mdic.gov.br/index.php/competitividade-industrial/setor-automotivo/rota2030/105-assuntos/competitividade-industrial/3780-legislacao-rota>
74. IEA. Tracking Transport. 2019
75. World Bank. Boosting Quality of Urban Transport Service in São Paulo. 2019
76. IEA. Bioenergy Task 39. 2019

2.2. Avoid and shift: public policies aiming at sustainable mobility

The Brazilian transportation system faces serious pressure given the country's continuous urbanization, the inefficiency of its transportation models, and the lack of investments to cope with the necessary modernization. The current mobility deficit exacerbates congestion and local air pollution.

These challenges are being intensified with the increase in the country's motorization rate. Between 2013 and 2015, the vehicle fleet grew by 111%, equivalent to 26 million new units[77]. However, active and public transport are still the main modes of transportation, especially for those living in low income communities. According to ANTP, 40% of trips are by foot or bicycle, 31% by car or motorcycle, and 29% by public buses in cities with more than 60,000 inhabitants[78].

Lower income communities are the most impacted by the poor quality of the public transport services, characterized by low frequency, crowded spaces and lack of safety. On average, they spend at least 20% more time on daily commutes when compared to the highest income share of the population[79]. This aspect is partially explained by the fact that economic opportunities are usually concentrated in the city centers as well as in higher income residential areas, while the poor population lives in the periphery of the metropolitan region.

Brazil has been implementing specific projects which aim to reduce the need for travel distances and promote low carbon modes. The country has focused on the implementation of bus rapid transit (BRT), particularly in cities such as Rio de Janeiro and Curitiba [Fig. 5]. The BRT can also be considered an "improve" strategy because it promotes service operational optimization. It combines the scrapping of older buses with higher control of transport operations. Some of its main benefits are greater efficiency and speed, as well as reasonable cost reductions. However, the BRT is facing challenges due to reduced political and investment support, causing frequent operational problems. In addition, the BRT competes for space with existing vehicle traffic, being commonly perceived as negative to the traffic flow.[80]

77. ITDP. Transporte y desarollo en America Latina. 2019
78. ITDP. Transporte y desarollo en America Latina. 2019
79. ITDP. Transporte y desarollo en America Latina. 2019
80. ITDP Sustainable Urban in Latin America. 2018

Figure 6. **Bus Rapid Transit (BRT) in Brazil**

Curitiba	
Inauguration	1974
Total extension	74 km
Total demand (passenger/peak hour)	20,500
Total demand (passenger/day)	566,500

Rio de Janeiro	
Inauguration	2011
Total extension	168 km
Total demand (passenger/peak hour)	65,400
Total demand (passenger/day)	3,178,600

Source: Global BRT Data. BRT Panorama. 2019 – Available at: <http://brtdata.org/location/latin_america/brazil/curitiba

On the other hand, other Brazilian cities are following different approaches. For example, São Paulo has implemented specific measures to restrict the circulation of motorized vehicles aiming to reduce traffic volumes and GHG emissions. The circulation restriction, known as rotation ("rodizio") was initially implemented in 1998. This measure regulates the circulation of cars into the city according to their license plates during different days of the week. This measure could promote fast reductions on local emissions, but it must be coupled with affordable and low carbon transportation alternatives.

In order to improve the transport sector towards a sustainable mobility system, governmental agents should promote integrated planning that takes into consideration cities' main challenges and needs, as well as particularities of their lower income inhabitants. Some Brazilian cities, such as São Paulo and Rio de Janeiro, have already announced plans to promote sustainable urban mobility systems[81].

In 2014, São Paulo established its 16-year Strategic Master Plan with its urban sustainable mobility strategy as one of its main pillars. It is focused on ambitious actions such as the introduction of parking policies, promotion of biking culture, and strong investments in mass transit[82]. Between 2014 and 2018, São Paulo created more than 400 kilometers of bicycle lanes. At the same time, the city aims to embrace bike sharing programs and ride-hailing services. It plans to make available 2,600 bikes through 260 solar-powered stations

81. Prefeitura do Rio de Janeiro. Decreto Rio N. 45781. 2019 – Available at: <http://smaonline.rio.rj.gov.br/legis_consulta/58128Dec%20 45781_2019.pdf>
82. World Bank. Boosting Quality of Urban Transport Service in São Paulo. 2019

across the city. By 2025, the city is expecting to allocate 97% of its population within 3 km of a public transport station – up from 25% today[83].

In 2019, Rio de Janeiro has also established its Plan for Sustainable Urban Mobility, after 4 years of dialogue and engagement with key stakeholders and society members. The plan proposes an alignment with the national urban development plan, as well as the prioritization of active transport modes over motorized transport. It takes into consideration the benefits of creating dense cities and transit-oriented strategies[84].

The cities' plans require resources both in funding and technical capacity, as well as political focus and willingness to observe their guidelines[85]. Therefore, politicians must be transparent, indicating milestones and tracking progress towards their targets.

83. Deloitte. São Paulo Mobility Index. 2018
84. Prefeitura do Rio de Janeiro. Decreto Rio N. 45781. 2019 – Available at: <http://smaonline.rio.rj.gov.br/legis_consulta/58128Dec%20 45781_2019.pdf>
85. SUTP. Sustainable urban mobility plans. 2017

3. FINAL REMARKS

Climate change increases the frequency of extreme weather events with economic implications and transport services' interruptions. In this sense, the transport sector has a critical role in keeping global temperature increases at 2°C due to its contribution to overall emissions and also to its exposure to climate change consequences.

New technologies, such as electric vehicles and autonomous driving, could contribute to the transport system emission reduction. However, further transformations are necessary to achieve global climate goals and a sustainable mobility system. It is necessary to consider a broader approach in order to develop effective plans to reduce the travel distances and promote low carbon modes alternatives.

In Brazil, the relevant participation of ethanol in the transportation energy mix reduces the pressure for further transformations towards a sustainable mobility system. However, more common extreme weather events and urbanization perspectives are already putting significant pressure on the current transportation system.

Brazilian cities have been implementing different strategies in order to promote a more efficient and accessible mobility, including urban mobility plans. **Taking into consideration the needs of lower-income inhabitants, as well as coping with political instability and complexity, represent the most significant challenges towards sustainable mobility in Brazil.**

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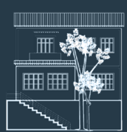

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