

Article

Using the Sustainable Development Goals to Evaluate Possible Transport Policies for the City of Curitiba

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Abstract: Cities across the world are becoming more engaged in tackling climate change and contributing to the achievement of international agreements. The city of Curitiba in Brazil is no exception. In December 2020, the city published PlanClima (Plano Municipal de Mitigação e Adaptação às Mudanças Climáticas), a climate plan developed with local and international organizations. PlanClima aims to guide policies and actions to mitigate and adapt to climate change. This study focuses on selecting and qualitatively evaluating transport policies that contribute to the city's 2030 climate and Sustainable Development Goals (SDGs). With PlanClima's analysis for the transport sector in mind, nine targets for 2030 are identified and connected to different transport policies. To evaluate the possible interactions between the policies and the different dimensions of the SDGs, four types of linkages were designed: essential, uncertain, limited, and opposite. These categories were developed to evaluate the several dimensions in which a policy can have a positive or negative impact. The results show that the implementation of zero emission zones/low emission zones, green public procurement, subsidy schemes for the uptake of clean vehicle technology, and the digitalization of the transport system through smarter public transport and digital platforms that couple bike sharing, taxis, and public transport are some of the measures that can contribute to the achievement of Curitiba's targets and ensure a positive impact on the sustainable development of the city. The study highlights how different policy instruments can contribute to achieve the city's targets, thus providing guidance to policymakers.

Keywords: transport policy; Sustainable Development Goals; climate targets; Curitiba; PlanClima



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1. Introduction

Globally, the transport sector is responsible for the second largest share of greenhouse gas (GHG) emissions. The sector contributed 24% of direct CO₂ emissions generated by fuel combustion in 2020. The rapid growth of transport sector emissions is mainly associated with road vehicles, which represent approximately three-quarters of the sector's global emissions [1]. Despite progress in electrification, and a decrease in the energy intensity of the transport sector, road transport emissions continue to increase. Therefore, an integrated, coherent, and coordinated set of policies is required to reduce the emissions of the sector. In 2015, the Paris Agreement was adopted, with the goal to reduce GHG emissions and limit global warming to well below 2 °C compared to preindustrial levels. Since then, 192 countries have made commitments to reduce emissions, as elaborated in their nationally determined contributions (NDCs) [2]. However, as most of the world population is concentrated in urban areas, the achievement of the NDCs depends on the engagement of local governments [3].

During the United Nations (UN) summit in 2015, heads of state and governments adopted Agenda 2030. The Agenda consists of 17 Sustainable Development Goals (SDGs) with 169 targets [4]. The SDGs focus on stimulating action for people, the planet, prosperity, peace, and partnerships. All these components have an integrated and interlinked nature that is crucial to the purpose of the SDGs. Five targets can be directly connected to the transport sector and several others can be indirectly related [5]. Therefore, the challenges faced by the transport sector, including congestion, road safety, energy consumption, pollution, can be connected to and evaluated within the context of these SDGs.

The SDGs and the NDCs are particularly intertwined in SDG 13, climate action, indicating the global recognition of the importance of addressing climate change and its impacts. In the past, several papers have been written in order to capture the interactions between sustainable development and transport policies. In 2012, an article described the interactions between policies targeting energy use in road passenger transport to reduce petroleum consumption and GHG emissions and sustainable development targets [6]. In 2020, an article demonstrated how integrated interventions for placemaking and active transport can contribute to a wide range of SDG targets [7].

Over the last few decades the engagement of cities in tackling climate change and ensuring a sustainable development has become crucial [8,9]. Despite their limited legal status under international law and sometimes autonomously from their nation state, cities have intensified their actions to reduce emissions and incentivize sustainable development. This has been incentivized by the construction of networks active in sustainable urban development and climate change, for example the C40 Cities Climate Leadership Group [10] or the Local Governments for Sustainability (ICLEI) [11]. C40 is a network of large cities around the world pursuing the common goal to reduce GHG and mitigate local and global climate risks through meaningful, measurable, and sustainable actions [10]. The city of Curitiba, in Brazil, joined this network in 2005 and under the Deadline 2020 initiative, developed a municipal plan to mitigate and adapt the city to climate change called “Plano Municipal de Mitigação e Adaptação às Mudanças Climáticas” (PlanClima) [12].

Curitiba is the capital of the state of Paraná, a southern Brazilian city of 1.9 million inhabitants with a metropolitan population of 3.2 million [13]. The city has a long history of innovative sustainable urban planning, particularly due to the introduction of the world-famous bus rapid transit (BRT) concept [14]. The BRT system was designed in the 1970s, consisting of special high-capacity buses running on fully dedicated lanes [14]. Today, Curitiba is a world reference for urban planning and smart environmental initiatives [15].

At present, to the best of the authors’ knowledge, few research studies have investigated how local transport plans can be translated into policy making that aims to achieve both climate and sustainable development goals. This paper aims to fill this research gap, by focusing on the transport sector of the city of Curitiba. The study starts by identifying the main targets of the city’s transport sector as expressed in PlanClima, and qualitatively evaluating possible policies for their achievement. In this way, this study aims to recommend possible policies to fulfil the goals present in PlanClima. Following this introduction, which also includes an overview of PlanClima, Section 2 describes the applied methodology. In Section 3, the goals of PlanClima for the transport sector are translated into nine targets and policies are researched to fulfill these targets. In Section 4, the results are discussed. Finally, in Section 5, conclusions and policy recommendations for the policymaking of the city are presented.

PlanClima

PlanClima was published in December 2020 with the purpose of guiding the actions and policymaking of the city of Curitiba to mitigate and adapt it to climate change. One of the sectors that PlanClima addresses is the transport sector, which is responsible for 66.6% of the city’s GHG emissions [12]. Within the plan, three scenarios were developed and this study focusses on scenario “estendido” (extended scenario). In this scenario a reduction of 78.1% of the city’s emissions by 2050, compared to the levels of 2016, is

modeled. To ensure this level of GHG emissions reduction, different actions, mitigation goals, and assumptions are described in PlanClima [12]. As can be seen in Table 1, for the transport sector, PlanClima focuses on fuel and technology changes for passenger cars, and a shift among the different modes of transport. Both of the assumptions, fuel switch and modal shift, have been designed with intermediate goals for 2030. For the fuel and technology changes, an introduction of electricity- and hydrogen-powered vehicles by 2030 is expected, with a combined share of 30% of all passenger cars by the end of the decade. For the modes of transport, an increase in trips by foot and by bicycle is expected, in combination with the introduction of a high capacity public transport system and a decrease in car travel. In PlanClima, a high capacity public transport system, is referred to as a public transport system with a higher capacity than the BRT.

Table 1. Technological assumptions and mitigation goals present in PlanClima for scenario “estendido”.

Mitigation Goals	Technological Assumptions 2030	Technological Assumptions 2050
2050: 100% of the transport sector fueled by clean or renewable energy	<p>Fuel and technology shift for passenger cars from 2016 to 2030.</p> <p>Fuel mix in 2030: ethanol, gasoline, electricity, and hydrogen.</p> <ul style="list-style-type: none"> Phase out diesel and compressed natural gas Introduce battery electric vehicles (BEVs) and achieve a share of approximately 20%; Introduce fuel cell electric vehicles (FCEVs) and achieve a share of approximately 8% Increase the share of ethanol from approximately 40% to 50% Decrease the share of gasoline fueled vehicles to approximately 23% 	<p>Fuel and technology shift for passenger cars from 2030 to 2050.</p> <p>Fuel mix in 2050: ethanol, electricity, and hydrogen.</p> <ul style="list-style-type: none"> Phase out gasoline Increase the share of battery electric vehicles (BEVs) from approximately 20% to 70% Increase the share of fuel cell electric vehicles (FCEVs) from approximately 8% to 15% Decrease the share of ethanol vehicles from approximately 50% to 15%
2050: 85% of transportation should be completed through public transportation or active mobility	<p>Modes of transportation:</p> <ul style="list-style-type: none"> Introduce a high capacity transport system and achieve approximately a share of 12% of all trips Reduce the percentage of car trips from 46% to 29% Increase the share of trips made by foot and by bicycle from approximately 25% to 31% Increase the share of trips made by motorcycle Increase the share of trips made by taxi Slightly decrease the share of buses and minibuses and replace them by the Bus Rapid Transit system and a high capacity public transport system in order to reduce the existent overlap of lines and routes 	<p>Modes of transportation:</p> <ul style="list-style-type: none"> Increase the high capacity public transport system from 12% to 25% Reduce the percentage of car trips from 29% to 6% Increase the share of trips made by foot and bicycle from approximately 31% to 38% Slightly increase the share of trips made by motorcycle Increase the share of trips made by taxi from approximately 2% to 6% Decrease the share of bus and mini buses and replace them by the Bus Rapid Transit system and the high capacity transport system in order to eliminate the existent overlap of lines and routes Increase the share of trips made through the Bus Rapid Transit system from 8% to 12%

PlanClima encompasses a list of 20 actions, from which three focus exclusively on the transport sector: expanding low carbon measures for the planning and management of the cities’ mobility; promoting active mobility, mainly by bicycle and by foot, through the improvement, expansion, and integration of services and infrastructure for bicycles and pedestrians; and promoting the renewal of the public transport fleet with the goal

to decarbonize and improve the cities' accessibility, air quality, and thermic comfort of the passengers [12]. In PlanClima, each of these actions is connected to the SDGs that it can potentially affect, however, no explanation is provided for the linkages established. For scenario "estendido", three main assumptions were made in PlanClima: an increase in vehicle efficiency; a significant increase in trips made by public transport and active mobility; and a significant decrease in the number of trips made by car. As can be seen in Table 1 two mitigation goals were defined for 2050 and in order to develop scenario "estendido" technological assumptions of fuel and technology shifts and distribution of modes of transport were made. Table 1 shows that the goal of scenario "estendido" is ambitious; in order to accomplish it a change in mobility paradigms, processes, behaviors, and technologies will be needed.

2. Methodology

In order to conduct this study four main steps were taken, as shown in Figure 1. As a first step the actions, mitigation goals, and technological assumptions, present in PlanClima, that apply exclusively to the transport sector, were identified. From these, nine targets were defined in order to capture the largest changes that need to occur by 2030 to achieve scenario "estendido" of PlanClima. For each of the nine targets, keywords were selected, based on the wording of each target, and a literature review was conducted to identify policies that can contribute to the achievement of each target. In addition, a literature review of existing transport policies was undertaken, and six keywords/phrases were selected: *transport*, *policies*, *decarbonization of the transport sector*, *review of policies*, *city-level policies*, and *sustainable development*. Several combinations of these keywords were researched, and the corresponding articles and reports were reviewed. The reviews were obtained using Google scholar, and a cap of 20 papers was imposed for each search. The papers and reports analyzed were from 2000 to 2021.

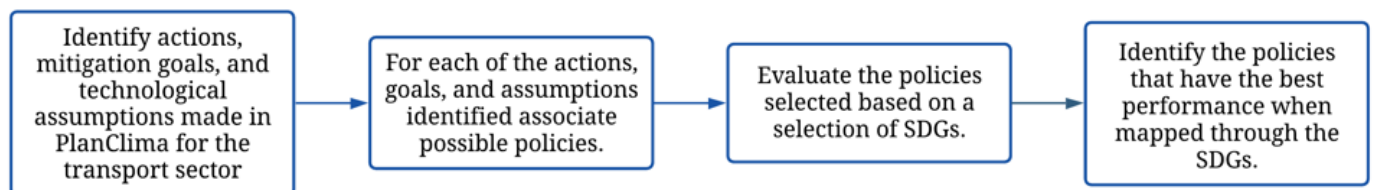


Figure 1. Workflow used to develop this study.

As a third step, the policies previously selected were divided into three categories (economic, regulatory, and information) according to the taxonomy develop by [16]. The SDGs were used as a lens to evaluate each selected policy, since different dimensions of the transport sector can be captured through different SDGs. In Figure 2, each of the dimensions evaluated can be seen. A selection of SDGs was made based on the ones highlighted for the transport sector in PlanClima and the different dimensions that could be evaluated through the SDGs. In this way, SDG 1, 3, 4, 7, 8, 9, 10, 11, 12, 13, 16, and 17 were selected. The impact on GHG emissions was captured using SDG 13 (Climate Action).

To assess each policy a systematic mapping of literature [17,18] was conducted in order to answer the question: How can each of the policies influence the dimensions captured by each SDG? To this end, studies were mapped to capture possible interactions between the policies identified in step 2 and the different dimensions of the SDGs. In order to map the studies, the words used to formulate the targets and the SDGs dimensions were defined as a research criterion. For the material collection, Google was selected in order to access both peer-reviewed articles and grey literature. Google scholar was used to find and select literature published in academic journals, and it was aided by Google search for finding and assessing grey literature. As grey literature, reports by international organizations, national, and subnational agencies were considered. The method used was adapted from previous studies evaluating SDGs linkages [19,20].





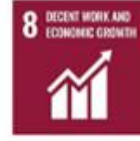







					
Affordability	Congestion, air pollution and road safety	Education for sustainable development	Energy efficiency and share of renewables in the energy mix	Job creation, innovation and economic growth	Sustainable infrastructure and research and development
					
Social and economic inclusion	Urban access, sustainable transport systems and sustainable cities	Fossil fuel subsidies, efficient use of natural resources	GhG Emissions	Participatory and representative decision-making and accountable and transparent institutions	International cooperation and policy for sustainable development

Figure 2. Dimensions of the transport sector captured by each SDG.

To evaluate the possible interactions between the policies and the dimensions of the SDGs, four types of linkages were designed: essential, uncertain, limited, and opposite. This was delineated based on the work developed by [6]. These categories were developed to evaluate the several dimensions in which a policy can have a positive or negative impact. Each category is based on the level of scholarly agreement identified within the mapping of literature and the availability of existing examples of implementation. An essential interaction (green color) reflects strong academic agreement of a positive impact between the policy and the dimension analyzed and the existence of successful implementation examples. Therefore, this interaction was identified when one or more peer reviewed articles or reports were found, and a case of implementation was documented. In order to identify this linkage no literature describing a negative interaction could be found. Uncertain (yellow color) indicates that a degree of disagreement in the area is apparent, with some cases of implementation proving to have a positive impact and others a negative impact. In this case if at least a positive and a negative article or report were identified this interaction was established. Limited interaction (orange color) indicates that no studies connecting the dimension and the policy were found. Finally, an opposite interaction (red color) reflects a negative impact of the policy towards an SDG dimension, in this case one study documenting a negative interaction was needed. In addition, no studies documenting a positive impact, or a lack of correlation between the policy and the dimension could be found. As a final step, based on the mapping of the policies, a recommendation of policies to achieve the city goals was made.

3. Targets and Policies

Based on the actions, assumptions, and mitigation goals present in PlanClima, nine targets were defined in order to summarize the main objectives for Curitiba's transport sector by 2030. These will ensure that Curitiba is on track with the achievement of scenario "estendido" by 2050. The nine targets defined were:

1. Increase vehicle efficiency;
2. Promote active mobility (pedestrians and cycling);
3. Reduce the share of trips made by car;
4. Promote the use of public transport through both the bus rapid transit system and the high capacity transport system;
5. Phase out compressed natural gas-fueled vehicles;
6. Phase out diesel-fueled vehicles;
7. Decrease the share of gasoline-fueled vehicles;
8. Promote the introduction of battery electric vehicles (BEVs);
9. Promote the introduction of fuel cell electric vehicles (FCEVs).

For each of the nine targets, a literature review of existing transport policies that can contribute to the achievement of each target was undertaken. During this search, articles and reports encompassing compilations and local implementations of transport policies that fulfill the targets were found. Table 2 shows the targets and corresponding regulatory, economic, and information policy instruments. As can be observed in Table 2, the policies that promote active mobility do not necessarily target walking and cycling per se, but instead have an indirect effect by discouraging automobile travel, which can create better conditions for walking and cycling. The same can be seen in "decreasing gasoline fueled vehicles" and "incentivizing battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs)". Among the different policies, green public procurement, implementation of stricter emission standards, implementation of Zero Emission Zones (ZEZs)/ Low Emission Zones (LEZs), and development of public awareness and information campaigns are associated with the highest number of targets, four or more. These policies are mainly related to targets that aim to reduce, phase out, or incentivize certain technologies.

Table 2. Targets identified in PlanClima and corresponding policies that aim to fulfill them.

Aim of the Policy	Possible Policies
Increase the efficiency of vehicles	<ul style="list-style-type: none"> • Fuel economy vehicle standards • Provide funding for R&D in vehicle efficiency • Provide tax incentives to encourage production and purchase of higher-efficiency vehicles • Implement fuel economy labeling • Provide low interest loans for the purchase of fuel efficient vehicles • Introduce extra fees for inefficient vehicles (feebates) • Promote eco-driving • Provide funding for the development of intelligent and connected vehicles • Provide subsidies for energy efficient vehicles
Incentivize the use of public transportation through both the bus rapid transit system and the high capacity transport system	<ul style="list-style-type: none"> • Lowering (or completely removing) public transport fares • Provide funding for new technologies to supply favorable services, such as an SMS ticket and downloadable public transport maps or timetables • Public awareness and information campaigns to incentivize the use of public transportation • Providing financing for public transport
Promote active mobility	<ul style="list-style-type: none"> • Provide funding to reallocate road space for cycling infrastructure and sidewalks • Provide funding for the implementation of a bike sharing system • Implement parking restrictions • Implement stricter speed limits • Public awareness and information campaigns to incentivize active mobility • Implement park-and-ride systems • Establish car-free zones • Implement congestion charging

Table 2. Cont.

Aim of the Policy	Possible Policies
Decrease the share of gasoline-fueled vehicles	<ul style="list-style-type: none"> • Implement tax schemes for gasoline-fueled vehicles • Green public procurement • Implement Zero Emission Zones/Low Emission Zones • Implement emission standards • Implement higher road tolls for new fossil-fuel cars • Implement higher parking fees for new fossil-fuel cars
Decrease the share of trips made by car	<ul style="list-style-type: none"> • Implement Zero Emission Zones/Low Emission Zones • Establish partial traffic bans based on time windows • Implement congestion charging • Provide funding to reallocate road space to cycling infrastructure and sidewalks • Introduce license plate restrictions • Establish car-free zones
Incentivize the introduction of battery electric vehicles (BEVs)	<ul style="list-style-type: none"> • Provide funding for self-service electric car hire scheme • Implement Zero Emission Vehicle mandates • Provide subsidies for BEVs • Provide funding for the expansion/implementation of Electric Vehicles charging infrastructure • Free Parking for BEVs • Public awareness and information campaigns to incentivize the purchase of BEVs • Implement emissions standards • Green procurement
Incentivize the introduction of fuel cell electric vehicles (FCEVs)	<ul style="list-style-type: none"> • Implement Zero Emission Vehicle mandates • Provide subsidies for FCEVs • Provide funding for the expansion of hydrogen refueling infrastructure • Provide funding for R&D in hydrogen-fueled vehicles • Free Parking for FCEVs • Public awareness and information campaigns to incentivize the purchase of FCEVs • Implement emissions standards • Green public procurement
Phase out compressed natural gas (CNG) vehicles	<ul style="list-style-type: none"> • Implement Zero Emission Vehicle mandates • Implement tax schemes for CNG vehicles • Green public procurement • Implement Low Emission Zones/Zero Emission Zones • Implement emissions standards
Phase out diesel-fueled vehicles	<ul style="list-style-type: none"> • Implement Zero Emission Vehicle mandates • Implement tax schemes for diesel vehicles • Green public procurement • Implement Low Emission Zones/Zero Emission Zones • Implement emission standards

4. Evaluation of Policies through the SDGs

The policies identified were divided into regulatory, economic, and information policy instruments, according to the taxonomy developed by [16]. These policies were then mapped using the SDG dimensions, which can be seen in Figure 2. For this, the selection of SDGs shown in Figure 2 was used, with SDG 13 (climate action) representing the reduction in GHG emissions. Each policy was evaluated based on the SDG dimensions, by using four different categories: essential (green), uncertain (yellow), limited (orange), and opposite (red). However, this method does not capture possible interactions between different policies, since it only evaluates each policy individually.

4.1. Regulatory Policy Instruments

Figure 3 shows the selected regulatory policy instruments. These policies encompass vehicle standards, vehicle access restrictions, and planning and infrastructure design. From all the policies mapped, implementation of stricter emissions standards; implementation of

ZEZs/LEZs; and reallocation of road space for public transport, bicycles and pedestrians are the policies that perform the best within the different dimensions of the SDGs.

As can be seen in Figure 3, stricter emission standards is the policy with the most documented and academic agreement of positive interactions. The implementations of tighter emission standards can have a significant influence in reducing CO, HC, NO, and smoke (particulate) emissions, which can contribute to a significant decrease in air pollution in cities [21]. However, depending on the design of the standards it may also have an increase in one of the above pollutants [21]. Nevertheless, this measure has been shown to significantly reduce air pollution in cities around the world [21–24]. By increasing the stringency of the standards, the deployment of progressively more effective and sophisticated technologies is needed. For example, diesel engine development for road vehicles has been mainly driven by more stringent emission standards [25]. The main shortcoming of this policy is that it may not contribute to an effective reduction in CO₂ emissions [24]. Even though this could be a possible policy to implement in Curitiba, the emission standards in Brazil are set by the federal government and not by the states or cities [26]. Nevertheless, this policy is currently being implemented in Brazil with the 2018 “Programa de Controle de Poluição do Ar por Veículos Automotores (PROCONVE)”. This includes two new emission standards, L-7 and L-8, which will come into force in 2022 and 2025, respectively [26].

	SDG1	SDG3	SDG4	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG16	SDG17
Implement stricter emission standards	Orange	Green	Orange	Green	Green	Green	Orange	Green	Green	Yellow	Orange	Orange
Implement stricter fuel economy vehicle standards	Orange	Yellow	Orange	Green	Green	Green	Orange	Yellow	Yellow	Yellow	Orange	Orange
Introduce driving restrictions through license plate restrictions	Orange	Yellow	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Yellow	Red	Orange
Implement Zero Emission Zones/Low Emission Zones (ZEZs/LEZs)	Orange	Green	Orange	Green	Green	Yellow	Orange	Green	Green	Yellow	Orange	Yellow
Reallocate road space to public transport	Orange	Green	Orange	Orange	Orange	Green	Green	Green	Green	Yellow	Orange	Yellow
Reallocating road space to cycling and pedestrian infrastructure	Orange	Green	Orange	Orange	Orange	Green	Green	Green	Green	Yellow	Orange	Yellow
Implement Zero Emission Vehicles (ZEV) mandates	Orange	Yellow	Orange	Yellow	Yellow	Yellow	Orange	Yellow	Green	Yellow	Orange	Yellow
Establish car-free zones	Orange	Green	Orange	Orange	Orange	Orange	Orange	Green	Orange	Yellow	Orange	Orange
Implement parking restrictions	Orange	Yellow	Orange	Orange	Orange	Yellow	Orange	Yellow	Orange	Yellow	Orange	Orange
Establish partial traffic bans based on time windows	Yellow	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Yellow	Orange	Orange
Implement park and ride systems	Orange	Yellow	Orange	Yellow	Yellow	Green	Yellow	Green	Orange	Yellow	Orange	Orange
Implement stricter speed limits	Orange	Green	Orange	Orange	Orange	Orange	Orange	Green	Orange	Green	Orange	Orange

Figure 3. Mapping of regulatory policy instruments. Four colors were used: green represents strong academic agreement of a positive effect between the policy and the SDGs, yellow means uncertainty, orange denotes a lack of specific studies in the area, and red represents a negative effect between the policy and the SDGs.

Implementation of Zero Emission Zones/Low Emission Zones (ZEZs/LEZs) is another policy with documented positive impacts in several SDG dimensions. This measure can potentially reduce particulate matter and NO_x emissions in the areas under the ZEZs/LEZs [27–30] and incentivize companies and individuals to adopt cleaner vehicles [30,31]. In addition, it can foster innovation in city logistics and boost modernization [31]. However, in order to achieve relevant results and avoid spillover a city-wide scheme should be implemented [32]. Additionally, GHG emissions may be reduced depending on the design of the ZEZs/LEZs policy. This will mostly depend on whether the measure will result in fewer vehicles, better traffic flows, and the uptake of zero or low emission vehicles (ZEVs/LEVs) [33]. Similar to ZEZs/LEZs, reallocating road space to bicycles, pedestrians, and public transport can contribute to the reduction in air pollution [34]. Moreover, this policy can contribute to the development of infrastructure that ensures a more sustainable city. Furthermore, increasing the walkability of cities and the quality of public transport can also contribute to social inclusion [35,36]. The reduction in GHG

through this policy will highly depend on the adoption of cycling, walking, and public transport by the population. In the Brazilian context, the lack of cycling infrastructure has been highlighted as one of the main barriers for students not to cycle [37]. Therefore, the implementation of this policy could promote active mobility. In Curitiba, there is a municipal plan being implemented that aims to build 408 km of bike lanes by 2025 [38]. In addition, Curitiba was the pioneer in the implementation of the BRT (Bus Rapid Transit) and is currently increasing BRT capacity and velocity through the expansion of the Inter 2 line [39]. This gives the city an advantage in implementing a successful high capacity transport system.

Restrictions through license plates was the only policy with strongly documented negative effects regarding any SDG dimension. For this policy measure, a tradeoff with SDG 16, participatory and representative decision making was found. In an article, after the implementation of this policy, 47.8% of the regulated car owners did not follow the restrictions and drove illegally to their destination places [40].

4.2. Economic Policy Instruments

In terms of economic policy instruments, taxes, subsidies, financing, and pricing instruments were found in the literature. Subsidies for ZEVs and energy efficient vehicles, taxes for fossil-fueled vehicles, lower or total removal of public transport fares, and providing funding for the implementation of bike-sharing systems are the policies with the most positive linkages. As illustrated in Figure 4, subsidies for ZEVs and energy efficient vehicles have positive linkages with several SDGs. For example, it can contribute to the reduction in air pollution in cities, mainly NH_3 , NO_x , and $\text{PM}_{2.5}$ [41], incentivize the uptake of energy efficient vehicles, and increase the amount of renewable energy in the energy mix. This policy may also have a positive impact on SDG 13, however this will depend on the emission intensity of the electricity used to power the BEVs or produce hydrogen [42]. In 2015, Curitiba had a carbon intensity of the electricity grid of 35 $\text{TonCO}_2\text{e/TJ}$ and Brazil had a share of approximately 66% of renewable energy in the electricity grid [43,44]. Subsidies for ZEVs and energy efficient vehicles is not designed with any specific goal of social equity, however any potential wealth disparity in accessing the subsidies could be addressed by instituting an income cap [45].

The implementation of a fuel tax will hinder affordability of transport and may contribute towards the social exclusion of the lowest classes [46]. Nevertheless, it may have a positive impact on the air pollution levels, GHG emissions, and incentivize a more sustainable consumption [47]. In contrast, lowering or totally removing public transport fares will contribute to social inclusion, through the mobility improvement of low-income people [48,49], and the affordability of the transport sector. However, there is limited evidence that there will be less automobile traffic, significant mode shifts to public transport, or less traffic congestion [50]. An undesired shift from walking or biking to public transport is also reported in different cities that applied this measure [48,50,51]. Funding for the implementation of bike-sharing systems can also expand active mobility [52] and in combination with the increase in infrastructure contribute to an increase in cycling. Other measures such as providing funding for smarter public transport, can contribute to an increase in the usage of public transport and the attainment of SDG 8, decent work and economic growth, and SDG 11, sustainable cities and communities. The two previous policies in combination with digital platforms that provide the integration of all mobility services, including bike-sharing, taxis, and public transport can foster multimodal mobility [53].

	SDG1	SDG3	SDG4	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG16	SDG17
Introduce taxes for fossil fueled vehicles	Red	Green	Orange	Green	Yellow	Yellow	Red	Green	Green	Green	Orange	Orange
Introduce extra fees for inefficient vehicles (feebates)	Red	Green	Orange	Green	Yellow	Yellow	Yellow	Green	Green	Yellow	Orange	Orange
Implement higher parking fees for new fossil-fuel cars	Red	Yellow	Orange	Yellow	Orange	Orange	Orange	Orange	Orange	Yellow	Orange	Orange
Congestion charging	Yellow	Green	Orange	Orange	Yellow	Orange	Yellow	Green	Yellow	Green	Orange	Yellow
Implement higher road tolls for new fossil-fuel cars	Red	Yellow	Orange	Yellow	Yellow	Orange	Yellow	Yellow	Orange	Orange	Orange	Orange
Provide subsidies for energy efficient vehicles	Yellow	Green	Orange	Green	Yellow	Orange	Yellow	Green	Orange	Yellow	Orange	Orange
Provide subsidies for Zero Emission Vehicles/Low emission Vehicles (ZEVs/LEVs)	Yellow	Green	Orange	Green	Yellow	Orange	Yellow	Green	Orange	Yellow	Orange	Orange
Provide low interest loans for the purchase of fuel efficient vehicles	Green	Yellow	Orange	Yellow	Orange	Orange	Yellow	Orange	Orange	Yellow	Orange	Yellow
Free parking for ZEVs/LEVs	Yellow	Orange	Orange	Yellow	Orange	Orange	Yellow	Orange	Orange	Yellow	Orange	Orange
Lower (or total removal) of public transport fares	Green	Orange	Orange	Orange	Orange	Orange	Green	Green	Orange	Yellow	Orange	Orange
Increasing financing for R&D for clean transport technology development	Orange	Orange	Orange	Yellow	Yellow	Green	Orange	Yellow	Orange	Orange	Orange	Yellow
Increase financing for R&D for increased vehicle efficiency	Orange	Orange	Orange	Yellow	Yellow	Green	Orange	Yellow	Orange	Orange	Orange	Yellow
Increasing financing for publicly available refuelling and charging infrastructure for ZEVs/LEVs	Orange	Orange	Orange	Green	Orange	Orange	Orange	Yellow	Orange	Orange	Orange	Yellow
Providing financing for public transport	Orange	Green	Orange	Orange	Orange	Green	Green	Green	Green	Yellow	Orange	Orange
Provide funding for the implementation of bike sharing systems	Orange	Green	Orange	Green	Green	Orange	Orange	Yellow	Green	Yellow	Orange	Orange
Provide funding for the development of intelligent and connected vehicles	Orange	Yellow	Orange	Orange	Orange	Green	Orange	Green	Orange	Orange	Orange	Yellow
Provide funding for self-service electric car hire scheme	Orange	Yellow	Orange	Yellow	Orange	Orange	Orange	Green	Orange	Yellow	Orange	Orange
Provide funding for new technologies to supply favorable services, such as SMS ticket, downloadable public transport maps or timetable	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Green	Orange	Orange	Orange	Orange

Figure 4. Mapping of economic policy instruments. Four colors were used: green represents strong academic agreement of a positive effect between the policy and the SDGs, yellow means uncertainty, orange denotes a lack of specific studies in the area, and red represents a negative effect between the policy and the SDGs.

4.3. Information Policy Instruments

As shown in Figure 5, several information policies were analyzed: standards (labelling), awareness campaigns, information provision, knowledge creation, and education. From these, both eco-driving and green public procurement, may have positive effects in reducing GHG emissions and air pollution [54–57]. However, awareness campaigns for eco-driving can have a short-term effect with drivers returning to their habitual behaviors [56]. This can be mitigated with dynamic eco-driving, where advice, depending on the traffic conditions, is given in realtime to drivers through the help of realtime traffic sensing and telematics [55]. Green public procurement can be a useful tool for cities, since it uses municipality purchasing power to shape the transport system into a more sustainable one [58]. A possible implementation of this measure is the introduction of ZEVs/LEVs in the bus fleet. However, the impact of this policy may vary significantly depending on how strictly the municipalities choose to set the requirements [59].

	SDG1	SDG3	SDG4	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG16	SDG17
Public awareness and information campaigns to incentivize the use of public transportation	Orange	Yellow	Green	Orange	Orange	Orange	Green	Yellow	Orange	Yellow	Green	Orange
Public awareness and information campaigns to incentivize active mobility	Orange	Yellow	Green	Orange	Orange	Orange	Green	Yellow	Orange	Yellow	Green	Orange
Public awareness and information campaigns to incentivize the purchase of clean vehicles	Orange	Yellow	Green	Orange	Orange	Orange	Green	Yellow	Orange	Yellow	Green	Orange
Introduce campaigns to promote eco-driving	Orange	Green	Orange	Orange	Green	Orange	Orange	Yellow	Yellow	Yellow	Orange	Orange
Green public procurement	Orange	Green	Orange	Green	Orange	Orange	Orange	Green	Orange	Green	Orange	Green
Implement fuel economy labeling (FEL)	Orange	Yellow	Green	Yellow	Orange	Orange	Yellow	Orange	Orange	Yellow	Green	Orange

Figure 5. Mapping of information policy instruments. Four colors were used: green represents strong academic agreement of a positive effect between the policy and the SDGs, yellow means uncertainty, orange denotes a lack of specific studies in the area, and red represents a negative effect between the policy and the SDGs.

5. Conclusions and Policy Recommendations

In this paper, 36 policies were evaluated qualitatively using a selection of SDGs. From these policies, the ones that performed the best, within the different SDG dimensions, were discussed for the context of Curitiba. This aims to provide policymakers with different policy instruments that can enable the achievement of Curitiba's 2030 climate and sustainable goals. The policies were divided into regulatory, economic, and information. Out of the regulatory policy instruments, stricter emissions standards, implementation of ZEZs/LEZs, and reallocation of road space for public transport, bicycles, and pedestrians were the ones with the most positive linkages with the SDGs. The implementation of ZEZs/LEZs is the measure that can influence the largest number of targets defined in PlanClima. Therefore, a quantitative study should be conducted in order to design ZEZs/LEZs that maximize the goals present in PlanClima and avoid possible spillover. Reallocation of road space for public transport, bicycles, and pedestrians is being implemented by Curitiba with the Plano de Estrutura Cicloviária, which aims to build 408 km of bike lanes by 2025. In addition, the long tradition of urban planning in Curitiba gives the city the required knowledge to expand the BRT and implement a high capacity transport system. Nevertheless, these two modes of transport will need to represent approximately 23% of the total number of trips made in Curitiba in 2030, which would entail the creation/expansion of lines and/or the increase in capacity of existent lines.

Among the economic policies, fuel taxes, subsidies for energy efficient vehicles or ZEVs/LEVs, and total removal/lowering of public transport fares were analyzed. Fuel taxes and total removal/ lowering of public transport fares had different positive and negative linkages. Fuel taxes had possible positive impacts in the reduction in air pollution and GHG emissions and removal/lowering the public transport fares contributed to social inclusion. However, removing/lowering the public transport fares had very little evidence of reducing air pollution or GHG emissions. Nevertheless, several designs for this measure exist, and depending on the city, it can have very different outcomes, therefore quantitative studies should be conducted. Regarding the implementation of subsidies, different levels of subsidies should be analyzed in order to make the purchase of ZEVs/LEVs competitive in comparison to internal combustion. At the same time, equality in obtaining the subsidies should be maximized, for example, by implementing income caps for accessing the subsidies. In order for the introduction of ZEVs/LEVs to be successful, charging infrastructure should be available in different locations of the city. Promoting active mobility through bike-sharing systems in combination with digital platforms that couple bike-sharing, taxis, and public transport can be another measure to implement in Curitiba. Digitalization that contributes to a smarter public transport and multimodal mobility can be an enabler of a more sustainable transport system for the city of Curitiba.

Green public procurement is another policy that can have an impact on a high number of targets. This could be implemented, for example, through the procurement of buses or refuse trucks fueled by electricity or hydrogen. In this way, green public procurement can contribute to the uptake of clean technology and the decarbonization of the city.

Further research should be developed in order to quantitatively assess each recommended policy and design it to maximize the achievement of the targets defined in PlanClima. In addition, the interactions between different policies should be studied, since in some cases it can highly influence their performance.

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