Simulations of Carbon Dioxide Emissions Related to the Use of Public Transport for Students in a Higher Education Institution in Southern Brazil

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Abstract: Carbon dioxide (CO₂) emissions from motor vehicles have been increasing in large urban centers, thus contributing to air pollution. The general objective of this study is to analyze simulations of CO₂ emissions among students who use public transport in the city of Passo Fundo, in the state of Rio Grande do Sul, Brazil. Methodologically, this study was developed in three stages: (1) verification of the time used by higher education students at Faculdade Meridional (IMED) in relation to urban mobility; (2) understanding of the transport mode used by these students, taking into account the one which appears with the highest incidence; (3) simulating CO₂ emissions from the modes of transport used by students after the application of the Environmental Impact Simulator (EIS) used by the National Public Transport Association (ANTP, in Portuguese) for the modeling of transport indexes aimed at analyzing CO₂ emissions. When considering the total of 3,079 students who assigned to a sample of 66 questionnaires, a reduction of CO₂ emissions of 4,527.04 kg during a year in relation to the use of public transport was found.

Key words: Public transport, urban mobility, environmental impacts, environmental analysis, pollution reduction.

1. Introduction

Several factors are crucial to reduce carbon dioxide (CO₂) emissions throughout the world. One factor that favors its reduction is to make use of energy efficiency, public transport and preservation practices as they are important mechanisms for sustainability [1].

At a global level, in the last decade high amounts of CO₂ emissions were registered due to the constant dependence on the burning of fossil fuels by motor vehicles, triggering environmental concerns in view of the upward compromise of air quality of cities [2, 3].

Although the automobile industry is opting for environmental policies to reduce CO₂ emissions globally [4, 5], high levels of CO₂ emitted into the atmosphere [2-5] need to be reduced by means of using technological innovations in order to mitigate them, thus reducing the negative effects on the human population’s health.

Human activities, such as increased use of fossil fuels for electricity consumption, transport, industrialization, landfills, among others, have been increasing the proportion of greenhouse gases [1]. Through these activities, the world population has been contributing to the global warming, thus it is crucial to have a better understanding of which impacts and lifestyles deserve greater attention, as there has been increased concern...
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about climate change [1].

Annually [6], levels of CO₂ emitted into the atmosphere correspond to an increase of 0.76%. However, with the increase in private vehicles and the decrease in buses in urban centers, the pre-existing dimensioning of road systems becomes inefficient and affects urban mobility [6, 7]. In addition, it disadvantages the population’s displacement regarding the use of other modes of transport, such as walking and cycling, thus it negatively impacts its quality of life [8].

Alongside this reality, it appears that this topic is included in the UN 2030 Agenda, which comprises 17 Goals with crucial themes related to humanity such as energy, water, poverty, health, among others. Regarding this, Goals 12 and 13, which present goals for “Responsible Consumption and Production” and “Climate Action”, clearly address the concern of mobilizing actors capable of promoting necessary changes [9].

The increase in demand for private vehicles, the lack of investments in quality public transport and the lack of planning for new mobility systems generate traffic congestion of motor vehicles on large road extensions, resulting in longer travel times at slower speed [8]. Private cars consume high amounts of fuel [5], therefore [10] they pollute greatly due to slow traffic and long travel time. In Brazil, public transport is less and less used by citizens with greater purchasing power, and they opt for the apparent flexibility and additional mobility provided by the private vehicle [8].

Due to the lack of inspection of the acceptable CO₂ emission level, most of the Brazilian vehicular fleet is responsible for affecting climate change, thus influencing the population’s quality of life [5, 6, 10]. Through the creation of public policies, it is possible to prioritize the reduction of gases emitted by motor vehicles, through economic instruments, with the allocation of taxes and subsidies assigned to those who respect the acceptable level of gas emissions [7].

The financial compensation is still very recent, but it refers to projects of which the population and companies buy credits. This value can be reversed to reforestation projects, renewable energies and also energy efficiency. This proposal is a type of negative externalities regarding reduction of CO₂ emissions [7]. However, they do not act directly to reduce CO₂ emissions, but to balance their levels with factors that purify the air with alternative actions for environmental conservation [7].

In an attempt to understand the excessive consumption of the population, one should understand that we find ourselves in a capitalist system, which seeks profit through various strategies without being concerned with the impact on the environment [11].

Unfortunately, air pollution and climate change policies go hand in hand and, for them to be effective in reducing global warming, both need to be integrated [10]. In this context, CO₂ is the main greenhouse gas, directly related to fuel consumption [12]. CO₂ reduction is crucial in achieving the 2 °C global temperature stabilization goal [10, 12]. Through data analyzed by the Institute of Applied Economic Research, in 2005 CO₂ emissions for Brazil were 2.123 million tonnes whereas in 2015 this number decreased to 1.368 million tonnes of CO₂. Thus, this decrease represents 35.9% reduction in the index. In addition, under the 2015 Paris Agreement, Brazil committed to reducing carbon emission levels to 1.208 million tonnes from 2020 to 2030 [12].

Therefore, according to the Brazilian Business Council for Sustainable Development [13], several measures must be taken in relation to different sectors such as energy, forestry, agriculture, industry and transport. By reducing CO₂ emissions, measures of greater efficiency, improvements in transport infrastructure and public transport in urban areas [13] are intended to be promoted. If this goal is reached by 2030, Brazil will be in a similar situation to the industrialized countries. Then, financial and tax mechanisms for a low carbon economy should be discussed [14]. Another alternative to reduce carbon dioxide and other gases harmful to the ozone layer is
the use of hybrid or electric buses. This possibility can reduce the traffic of individual vehicles, as well as contribute to the reduction of greenhouse gases in cities [15].

Reducing the use of automobiles in large cities involves behavioral changes at individual and collective levels, in addition to changes in the existing urban infrastructure [14]. For these changes to take place, it is necessary to involve the municipal and federal spheres of the government, in addition to the participation of the population [14, 16]. The correct planning must be foreseen by considering new transport modes, investment in quality of the existing network infrastructure, and education and awareness of the population on more sustainable uses of these systems. At the same time, the government needs to improve accessibility conditions in Brazilian urban centers so that public transport meets mobility needs efficiently and effectively with universal accessibility [16]. Finally, the population must seek alternatives in terms of preferred mode of transport for daily commuting [5]. The analysis of international studies on reduction of car use pointed out that the offer of public transport of good quality combined with public policies that attract new users must be a continuous and constant work [14, 16].

In this context, public transport such as bus services must be used more assiduously by the population living in areas furthest from the center. According to the National Association of Public Transport Yearbook, during the last 20 years, bus service as one of the Brazilian public transports had an overall reduction of 35.6% in passenger numbers [17]. However, the demand for users has shown a more significant reduction in the last 5 years, representing about 25% of the reduction in paying users [17]. Unfortunately, with the decrease in the number of users, the price of the tariff has to increase, dividing the operating costs among the portion of the population that makes use of it.

As a result of the factors presented above, it can be asserted that private transport is still increasing due to the rapid need for mobility and the greater ease of using these vehicles [18]. However, there is the possibility of car sharing, which reduces traffic volume [19-22].

However, as there was an increase in vehicles in urban centers, air pollution increased, causing harm to the quality of life of the general population. Thus, the goal is to improve the following: transport conditions, fuel economy, reduction of gas emissions in the atmosphere, reduction of congestion on the streets, reduction of urban noise and the effective appropriation of public spaces by pedestrians. The general objective of this study is to analyze CO₂ emissions in the city of Passo Fundo/RS-Brazil, through simulations among students of Higher Education at Faculdade Meridional (IMED) who use public transport.

2. Method and Materials

The municipality of Passo Fundo is located in the northwest region of the state of Rio Grande do Sul, in Brazil. It has an area of 783,603 km², with an approximate population of 203,275 inhabitants, resulting in a density of 235.92 inhabitants/km² [23].

This is a qualitative study which helps researchers to understand social, cultural and institutional contexts [24]. Through the use of this method, it was sought to identify how long it takes students from the higher education institution Faculdade Meridional (IMED) to travel from the starting point (residence/work place) to their arrival point (IMED). Depending on the academic year, these students attend their courses at IMED either in the morning or in the evening. Also, a diagnosis was made to identify areas that have the longest travel times traveled by students.

This research study is divided into three methodological stages:

Stage I—The allocation of theoretical contribution through bibliographic research in order to obtain a greater foundation on urban mobility and CO₂ emissions to the atmosphere in relation to levels and amounts;
Stage II—Data collection from an online questionnaire to IMED students. A total of 3,079 students were considered. The Sample Calculation method was used, with a confidence level of 90% and a sampling error of 10%. Sixty-six (66) online questionnaires were applied. Then, the Declared Demand Method [25] was applied online to undergraduate students enrolled at IMED.

Stage III—Application of the simulator which helped to analyze the travel time taken by IMED students, between two points, that is, the starting point and the arrival points (institution). The mode of transport used was verified. Afterwards, a gas emission simulator for each mode of transport used by the students was applied. This was the Environmental Impact Simulator (EIS) of the National Association of Public Transport (ANTP, in Portuguese) [26], with the simulation of different indexes of public transport and their gas emissions.

3. Results and Discussions

The application of the online questionnaire made it possible to identify the main starting points of IMED students, taking the travel duration and the most used modes of transport. Based on this information, it was identified that most students move from downtown (28% of the respondents), then from São Cristóvão (12%), Vila Rodrigues, Vila Annes and Petrópolis suburbs (7%). In addition, 80.3% of respondents aged 15 to 25 years, followed by 13.6% aged 25 to 35 years and 6.1% aged 35 to 45 years. Also, 66% are female and 44% male, with an income below four minimum wages (38.4%). It is noteworthy that in Brazil the minimum wage is R$ 1,100.00 reais (USD 205.15).

It is noticed that 63.6% of the students take evening classes and 36.4% morning classes. Of these students, 81.8% are still pursuing higher education, and 10.6% have already completed higher education and are undertaking a second degree. In addition, 33.3% of these students use cars to travel from their starting point to their arrival point, 28.8% use public transport and 24.2% walk. Individual motorized transport leads to an increase in the city’s vehicle fleet which often during peak hours and rainy days results in traffic congestion and slow traffic, thus taking longer to move [26-28]. Another point to consider is the use of car sharing services, which becomes a sustainable mode for the transport system [29].

The average time spent in commuting is 23 minutes and 44 seconds a day, considering the suburbs as the origin point, and IMED the arrival point, and taking into account all modes of transport. After identifying the travel time characteristics and the initial displacement of the use of the car fleet circulating in Passo Fundo, the use of bicycles—a more economical and certainly less polluting mode of transport—was simulated. Only 50% of the vehicle fleet was analyzed in order to take into account a situation which is possibly applicable to daily life. As a result of such substitution, the ANTP EIS [26] demonstrates an increase of 11% in relation to the time spent by users in traffic. This square footage of roads occupied by the users would reduce by 31% as bicycles occupy smaller spaces than cars. When energy expenditure is concerned, this substitution would provide a 37% reduction as well as a decrease in local pollutants, which represents a 26% decline and, obviously, a 30% CO₂ reduction if everyone used bicycles. The reduction of these emissions would have an impact on human health and the environment [18].

The main suburbs from which students pointed out as a starting point for moving to IMED were identified for a new simulation regarding CO₂ reduction in each route. To this end, the centroids of each suburb were identified. After obtaining the information regarding the distances to the educational institution IMED, a simulator from the Federal University of Paraná (UFPR) [26] was used, and the distances, five days of weekly displacement, and an average of two trips per day were considered. Thus, a change in mobility management can make space-time accessibility measures more sustainable [29].
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Through this analysis, it can be verified that if one person per indicated suburb travels to IMED by car for five days a week, considering a return trip, decides to use public transport for the same route, there will be a reduction of gas emissions of 4,527.04 kg per year.

In addition, the number of responses originating from each starting point to IMED was also considered. This number was multiplied by the distance and the reduction of gases. If this route was performed by bicycles, there would be a monthly reduction in the emission of polluting gases of 3,623.94 kg and an annual reduction of 43,487.22 kg.

This study contributes to the literature of issues regarding the use of modes of public transport such as buses, trains and subways available in some cities, as well as bicycles as they have a great potential for operational efficiency and environmental impacts [18].

4. Conclusions

The reduction in use of automobiles in large cities involves individual and collective behavior changes, as well as changes in the existing urban infrastructure. For these changes to occur, it is necessary to involve the municipal and federal spheres of the government, in addition to the participation of the population.

The studies conducted by international studies on the reduction of use of cars pointed out that the offer of public transport of good quality combined with public policies to attract new users must be an ongoing and constant work. Such changes can bring advantages such as better transport conditions, fuel savings, reduced gas emissions into the atmosphere, less traffic congestion on streets, reduced urban noise and, not least, the effective appropriation of public space by pedestrians.

By carrying out this research study, it was possible to contribute to research literature on the topic of CO₂ emissions in relation to IMED students’ use of public transport. Thus, it was shown that when considering the total of 3,079 students assigned to a sample of 66 questionnaires, there was a reduction in CO₂ emissions of 4,527.04 kg in a year related to the use of public transport. This is associated with the education and awareness of students regarding conscious use and the possibility of alternative transport modes.

This study suggests that more research aimed at monitoring the levels of CO₂ emissions into the atmosphere with the possibility of creating public policies that can encourage the use of public transport, not only by students, but by other social audiences should be carried out. This can significantly contribute to the reduction of CO₂ emissions in cities.

It is also worth mentioning the importance of countries to create new mobility plans, as well as to increase investments in infrastructure for bicycles, buses and other modes of public transport.

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