

Evaluation of the impact of the use of bicycles, in place of the motorcycles, on the reduction of carbon dioxide (CO2) emissions, on last mile operations in brazilian postal service.

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Abstract. The concern about the increase in vehicle traffic in large cities, largely driven by the activities of distribution of objects from e-commerce, has generated a constant and growing concern in public administrations and society, due to the problems of circulation of vehicles powered by fossil fuels in urban roads, increasing atmospheric emissions and worsening people's quality of life. Through a comparative analysis, simulating the migration of motorcycles to bicycles in the operations of delivery of messages and small orders in the Brazilian Post Office Company (Correios) of the Federal District, the present study aims to estimate the potential reduction of emission of gases resulting from logistics activities due to the change of modal, from motorcycles to bicycles, using a pollutant conversion formula and a sample of the circulating fleet of the Correios to define the emission of toxic gases emitted by this operation. The results demonstrate the logistics segment as a relevant pollutant emission agent and the importance of converting the fleet to more sustainable solutions.

Keywords: Last Mile, Cyclologistics, Sustainability, e-Bike, Cargo Bike, Smart Cities.

1 Introduction

The modernization in the management of cities, which require smarter mobility solutions, combined with changes in the behavioral aspects of society, which requires more sustainable logistics operations, modern and integrated with the urban environment, has encouraged companies and citizens to adopt less polluting and more flexible transport modals of locomotion in urban centers. Recently, urban cargo transport (macro level) and door-to-door home distribution (micro level) are one of the most important topics on the smart cities agenda in the world. Aspects such as mobility restrictions in urban areas, e-commerce growth, pressure by consumers for increasing levels of services in logistics and debates on carbon dioxide (CO2) emissions [1] are challenges that emerge day by day in the ecosystem of large cities.



The growth of traffic in the city grids is seen as one of the biggest problems for local authorities, where the delivery of products purchased by e-commerce is an additional aggravation factor for the problem of congestion and, therefore, pollution. Between 8 and 18% of urban traffic results from the circulation of vehicles with delivery operations, which decrease by about 30% the flow of the streets, due to the characteristic of constant stops of vehicles operating in the logistics of last mile.[2] [3]

A viable alternative to part of this problem involves migrating the equipment park to more sustainable transport solutions, integrated into the urban environment. In areas with higher population density, up to 51% of the trips made by combustion vehicles could be performed by bicycles and cargo bicycles [4], which highlights the feasibility of this solution as an option to modernize urban logistics operations.

The environmental issue is increasingly important in this debate, and the transport segment emerges as an important issuer of toxic gases into the atmosphere. In 2016 about one-fifth of the total gas emissions in Europe came from the transport segment, 72% specifically from road transport, which ranks this industry as the second in the ranking of the most polluting on the European continent [5]. In the United States, the transportation sector accounts for about 37% of all CO2 emitted in the atmosphere [6], with a constant and accelerated growth trend, which makes the theme relevant to society and future generations.

The Brazilian logistics scenario, where 61% of all cargo transfer in the country occurs by road [7], aggravated by intense congestion and a large concentration of pollutants in large metropolises, demands constant analysis and searches for new models of last-mile operations.

Even with the recent reduction in the movement of people and vehicles due to covid-19 containment actions in the country, Brazil has some of the most congested metropolises, with 5 cities among the 60 with the highest traffic in the world [8]. In the cities of Recife, Rio de Janeiro, Fortaleza, Salvador and São Paulo, the routes took about 30% more, on average, due to congestion problems. This phenomenon necessarily generates higher cost, lower productivity and greater pollution in logistic operations.

In the database of the System of Estimates of Greenhouse Gas Emissions and Removals (SEEG) the energy segment, in which the transport sector is inserted, is responsible for 18% of all carbon dioxide emitted in the environment in Brazil, as shown in Figure 1. In Brazil, the most populous municipalities have in the Energy sector their main source of emissions, mainly due to the consumption of fossil fuels in transport. [9]





Fig. 1. Total CO2 emissions in Brazil from 1990 to 2020

The migration of the transport industry to greener technologies and operating methods: modern and sustainable, permeates a series of changes, equipment and processes, which must be analyzed in a common strategy, with a well-defined plan. One of the technologies that present a consistent result for this problem, under specific conditions, is the use of bicycles in urban logistics of distribution in the last mile.

In Brazil, it is evident the financial vantajosity of the adoption of bicycles in the distribution of cargo, to the detriment of combustion-powered equipment (trucks and motorcycles) [10]. There are, however, additional challenges such as the lack of education of other drivers and the deficient urban infrastructure, which are pointed out as the main barriers to the massification of cyclelogistics in Brazil. The issue of infrastructure is seen as the main barrier to the use of cargo-bikes also in European cities, which reinforces the importance of public policies addressed to this theme, as a critical element in the promotion of bicycles in logistics. This scenario stems from the importance of public investment in urban infrastructure, in partnership with logistics companies in general. [11] [12].

2. Objectives

The study seeks to analyze the level of gas emissions in the delivery operations of mail and small orders in the Post Office Company in the Federal District – Brazil, showing the potential for gain, from the environmental aspect, from the replacement of conventional equipment to combustion by bicycles.



With the exposure of the relevance of the theme, it seeks in a secondary way to stimulate the migration of the use of combustion equipment to means of locomotion more friendly to the environment and urban infrastructure, especially in large centers.

3. Material and methods

The research was characterized as a case study. This type of research consists of an "empirical observation that investigates a contemporary phenomenon within its reallife context, especially as to the limits between the phenomenon and the context are not clearly defined" [13].

3.1. Area studied

The area of coverage studied was limited to the territory of the Federal District (region shown in Figure 2), through the information obtained from the Brazilian Post and Telegraph Company (Correios), regarding the parameters adopted to size the number of routes, the types of modals and the extensions of the courses made by the postmen, to carry out daily the delivery and collection of mail and small orders in the region of interest of the study, which includes all urban neighborhoods with regular delivery performance by Correios in Federal District.



Fig. 2. Federal District Region

The Federal District presents some relevant indicators in the Brazilian environment, being the Federation Unit with the highest Human Development Index (HDI), according to the HDI ranking 2020 of the United Nations Development Program (UNDP), besides presenting a differentiated urban infrastructure in the aspects of organization and investment in bicycle paths, where Brasilia emerges as the second city in the country with the largest network of bike paths (465Km), behind only São Paulo. However, with a small territory, the population of the Federal District repre-



sents only 1.4% of the resident population compared to the total population of the country [14].

In Correios, this correlation is also observed, where Federal District represents 1.8% of the routes served by motorcycle around the country (308 out of 17,100).

Despite the restricted sample, considering the percentage of the motorcycle fleet in operations at the Federal District compared to the total in use in the company, the environmental impact of the urban logistics of Correios is considered significant.

The evaluation was limited only to those performed on motorcycles and bicycles, adopted by the Brazilian Post Office for the distribution of mail and small orders. It was not part of the study, therefore, the vehicles made by light and heavy vehicles, which are used for the distribution of orders of greater volume.

3.2. Data collection and studies

The primary source of the data that served as the basis for analyzing the research were the reports of the District System (SD), which is a proprietary tool of Correios. Such software is adopted in the company to plan the allocation of resources in distribution in all municipalities of the country.

Briefly, the SD has registered in its parameters standard coefficients of times and yields, both internal activities of preparation of the load and of the external activities of door-to-door distribution by the postmen, which are inserted in the data base and updated regularly through chronoanalysis studies.

The tool has also registered all delivery segments, having each street's Postal Address Code (ZIP Code) as a search key.

Finally, in defined cycles, the operational team of each Home Distribution Center (CDD) migrates data from other system bases that have crawling objects (such as small orders and pouches, for example) and also manually enter data from untraceable objects (such as letters and magazines, for example). Combining the parameters of excerpts, the standard times for each activity, and the registration of demand (through incorporation or manual posting of data), the SD defines the operational need and the appropriate modal to meet each segment, where the composition of several conurbade ZIP Codes form the workload of a postman, who receives the name of postal district. Finally, the composition of the workload of a defined number of postmen composes a CDD that serves a particular region of the city.

In the Federal District, Correios has 23 CDDs where 495 postmen work, distributed throughout the territory, acting in diverses modals, sized for each delivery region.



The following table presents the forecast of pedestrian postmen and the circulating fleet of motorcycles and bicycles, in use in the daily distribution activities of the Post Office of the Federal District.

Table 1. Fleet operating on the routes of delivery of mail and small orders in the Post Office	e
in the Federal District	

REGION (CDD)		NUMBER OF D	ELIVERY ROUTES	
_	MOTORCY CLE	BICYCLE	PEDESTRIANS	TOTAL
Aguas Claras	19	5	0	24
Asa Norte	5	0	13	18
Asa Sul	10	0	10	20
Setor de Industria e Abastecimento	14	4	5	23
Ceilândia	2	0	31	33
Ceilândia Sul	3	0	24	27
Gama	2	13	0	15
Guara	7	0	16	23
Lago Norte	3	18	4	25
Lago Sul	10	0	0	10
Nucleo Bandeirante	9	1	5	15
Planaltina	8	0	22	30
Recanto das Emas	1	4	20	25
Fern	4	12	19	35
Santa Maria	3	11	0	14
Sao Sebastiao	4	0	17	21
Sobradinho	12	0	2	14
Taguatinga Leste	2	14	0	16
Taguatinga Centro	3	3	6	12
Taguatinga Norte	9	0	0	9
TOTAL	167	85	194	409

For this article, the basis of the Federal District report in the SD was used, consulted on 01/24/2022, with the most recent demand information of each section of the Distribution Center that operates in each location. As previously mentioned, the distribution of larger volume orders, which are distributed by about 450 additional vehicles, was not part of the scope.



The same system presents the sized fleet of motorcycles of Correios in the Federal District, as shown in the table below.

Madal	Makar	Q	uantity per yea	ar of manufactu	ıre
wodei	waker	2013	2019	2020	Total
CG 125 Cargo	Honda	32	-	-	73
CG 160 Cargo	Honda	-	37	72	109
NXR 160 Bros	Honda	-	41	-	41
Total		32	78	72	182

Table 2. Number of motorcycles in Correios of the Federal District

The number of motorcycles (182) is slightly greater than the amount of the circulating fleet (167) due to the reserve fleet and the vehicles retained for maintenance: preventive or corrective. The prediction of motorcycles effectively in door-to-door daily distribution is reported in table 1, totaling 167 vehicles.

The distribution of fleet by distribution unit is exposed in the following table:

Table 3. Distribution of motorcycles at the Post Office by Region of the Federal District

Region (CDD)	CG 125	CG 160 CARGO	NXR160 BROS	General
	CARGO			Total
Aguas Claras	4	7	4	15
Asa Norte	3	4	3	10
Asa Sul	3	9	3	15
Setor de Industria e	1	14		15
Abastecimento				
Ceilândia	2	3	1	6
Ceilândia sul	2	4	1	7
Gama		2	1	3
Guara	1	6		7
Lago Norte	1	4	3	8
Lago Sul		11	2	13
Núcleo Bandeirante	3	6	3	12
Planaltina		4	4	8
Recanto das Emas		1	2	3
Samambaia	3	8	1	12
Santa Maria	2	2	1	5
São Sebastião		1	2	3
Sobradinho		9	4	13



Taguatinga Leste	3	1	1	5
Taguatinga Centro	3	7	2	12
Taguatinga Norte	1	6	3	10
TOTAL	32	109	41	182

To enable the calculation of the emission of gases from motorcycles, the parameters of CETESB (Environmental Company of the State of São Paulo), which is an agency linked to the Secretariat of Infrastructure and Environment of the Government of the State of São Paulo, responsible for the control, supervision, monitoring and licensing of pollution-generating activities in the state, were used.

CETESB has issued, since 2011, the Report of Vehicular Emissions in the State of São Paulo, with an analysis of the circulating fleet and emissions of local pollutants and greenhouse gases in the state. The following table presents a summary table with the emission of pollutants, considering the fleet (years and models) of motorcycles used by Correios in the Federal District.

Table 4. CETESB pollutant emission factor table

YEA R	CLAS SIFICATI	FUE L	со	нс	NM HC	CH4	NOX	MP	CO2	N2O	AUT ONOMY
	ON		(g/K m)	(km/ l)							
2013	≤ 150 cc	Pet- rol	0,492	0,16 0	0,12 0	0,04 0	0,06 3	0,00 35	56	0,00 2	40,9
2019	≤ 150 cc	Pet- rol	0,566	0,11 1	0,08 3	0,02 8	0,02 3	0,00 35	39	0,00 2	55,9
2020	≤ 150 cc	Pet- rol	0,537	0,11 5	0,08 7	0,02 9	0,02 3	0,00 35	43	0,00 2	50,9

CETESB also defines a calculation equation, which is considered as a national reference for calculating atmospheric emissions in Brazil [15].

E = Iu x Fe x Fr

- E = Total emission, or pollutant mass emitted in the considering period (g/year);
- Iu = Intensity of use or average annual mileage traveled by the vehicle (km/year)
- Fr = Rolling fleet (g/km)
- Fe = Emission factor (g/km)

The intensity of use (Iu) and the rolling fleet (Fr) was obtained thought the quantity of equipment and the average distance predicted for motorcycles, based in information obtained from the Post Office. The emission factor (Fe) was obtained thought the table 4.



The calculation parameter of tree planting compensation adopted the fixed factor of 7.14 trees for each ton of CO^2 emitted, based on an study of native tree species plantations for restoration in Brazil in 2009 [16].

The study sought the grouped simulation of carbon dioxide emissions throughout the territory of the Federal District in post office operations, without particularizing any region.

4. Results and Discussions

The following table presents the extract of the tours sized for the postal delivery of mail and small orders in Federal District, which are carried out by postmen cyclists, pedestrians and bikers. In all, the population served is of the order of 2.78 million people, distributed in 41,372 streets.

The daily installed capacity planned for distribution in Brasilia is about 450,000 letters and 70,000 small packages, which are distributed by bicycles or motorcycles (in addition to bulky packages, which are distributed by vehicles).

The following table presents a summary of the daily distances, by delivery region, in Federal District.

REGION (CDD)	DAILY DISTANCE TRAVELED (Km)				
-	MOTORCYCLE	BICYCLE	TOTAL		
Aguas Claras		360,9	360,9		
Asa Norte		235,3	235,3		
Asa Sul		180,4	180,4		
Setor de Industria e Abasteci- mento	98,2	278,3	376,4		
Ceilândia	462,7	321,8	784,5		
Ceilândia sul	161,7	115,9	277,6		
Gama	330	106,1	436,1		
Guara	130,7	167,8	298,6		
Lago Norte	317,4	287,5	604,9		
Lago Sul		495,5	495,5		
Núcleo Bandeirante	14,6	434	535,1		
Planaltina	283,9	269,3	553,3		

 Table 5. Daily distances traveled by postmen in the distribution of messages and small orders in the Federal District



			/
TOTAL	2.854,20	5.019,96	7.874,1 7
Taguatinga Norte		377,5	377,5
Taguatinga Centro	99	48,3	228,8
Taguatinga Leste	260,9	66,8	327,8
Sobradinho	27,5	660,7	688,2
São Sebastião	43,7	158,7	391,1
Santa Maria	221,8	135,5	357,3
Samambaia	299,2	245,3	564,7
Recanto das Emas	102,9	74,3	435,6

The location of the Distribution Centers recommends the most condensed urban groupings and, not necessarily, the official division of the Administrative Regions of the Federal District. For this reason, some regions such as Ceilândia and Taguatinga have more than one CDD, because they have a workload higher than the expected capacity of an operational distribution unit, while other regions such as Riacho Fundo and Cruzeiro are served by the Distribution Center located in a nearby region. In any case, the entire urban population of the Federal District has service by regular home distribution of the Post Office, through these 20 CDD and with these distances traveled daily.

Despite some longer journeys, in general, deliveries made by motorcycles in Correios are concentrated in short routes, where almost 60% of the travels have a total distance of less than 15Km, as shown in Figure 3. This particularity is a characteristic in the distribution operations of mail and small orders in fractional load, which have higher load density, that is, a greater amount of delivery points per kilometer than the grouped load distribution operations, for example.





Fig. 3. Number of motorcycles x distance traveled for the distribution of messages and small orders in the Federal District

The simulations of the study present a theoretical analysis of migration of motorcycles to bicycles, segmented into 3 scenarios:

Scenario I - Total migration of all motorcycle rides for bicycles;

Scenario II - Migration of all districts served by motorcycle with total daily ride of less than 25 km, for bicycles; and

Scenario III - Migration of all districts served by motorcycle with a total daily ride of less than 15 km, for bicycles.

The results of emission of CO^2 were obtained by analyzing the circulating post office fleet (Fr), the average daily distance traveled (Iu) in the federal district by motorcycle and the emission factor (Fe) defined for each type of motorcycle, as explained in item 3.2. Applying the pollutant emission conversion formula, it is possible to analyze the degree of CO^2 emission in the operations of the Post Office in the locality.

Scenario I is considered operationally unfeasible, considering the difficulties of integral and immediate modal migration and the difficulties of urban infrastructure for the full expansion of bicycle distribution in the short term in all regions of Federal District. In any case, this scenario, with migration of 5,019 km daily (110,418 km per month) of motorcycles for bicycles, exposes the maximum capacity of CO^2 reduction and, also, serves as an alert for this theme in the strategic planning of distribution resources.

Based on these criteria, and using the resulting of pollutant emission equation, the expectation of daily CO² reduction in Correios in Brasilia extinguishing all the deliveries of messages and small orders by motorcycles and migrating them in their entirety to bicycles, conventional and electric, would be about 140 Tons of carbon dioxide



monthly, considering a linear distribution operation over 22 days per month and 12 months per year.

Analyzing annually, this total represents about 1,680 tons of CO^2 taken from the environment, and the equivalent of planting about 12,000 trees, projecting an ecological compensation for neutralizing the effective stakes of these gases in nature.

Scenario II is considered optimistic, as it proposes the migration of motorcycle districts with a daily ride of less than 25Km for bicycles, assuming that the shorter distances are likely to be carried out by equipment without combustion engine.

This scenario predicts that about 80% of motorcycle rides would have modal migration, with 2,967 km daily (65,274 km per month) being performed by bicycles in place of motorcycles. The result of the simulation was the reduction of 82.7 tons of CO^2 per month in the atmosphere, or the equivalent of the annual planting of about 7,000 trees for environmental compensation.

Scenario III is considered realistic and capable of implementation in a shorter period of time, because it involves less operational adaptation, investment and the need for infrastructure to perform, because it considers the migration only of the districts whose daily travel is less than 15 km, which represent about 56% of the total. These parameters cover a total daily journey of 1,620 km that would no longer be covered by motorcycles and would be operated by bicycle.

In this scenario, the emission of CO^2 simulation indicates a daily reduction of 2 tons of pollutants in the atmosphere, equivalent to the annual planting of almost 3,800 trees for environmental compensation.

5. Conclusions

Even in the most conservative scenario of the study, the expectation of gas emission is relevant, which highlights the degree of importance of the environmental theme in the planning of the Post Office and logistics companies in general.

The study analyzed only one of the aspects involved in the decision-making process, which is the issue of carbon dioxide emissions, and only in the fleet of the Post Office in circulation in the Federal District. Therefore, it would need to expand the evaluation to other aspects, such as the financial one involving the need for investment, the operational flow, with the impacts on the productivity of distribution when migrating modal, and the feasibility of implementation considering the urban infrastructure available in each specific region of interest.

In any case, it is considered essential in the current scenario of smart cities and engaged society, the concern and effective action of mitigating the environmental impacts in its operation, and knowing the impact of the emission of gases that impact on



the effective greenhouse is one of the most important initial steps to effectively outline a strategy for the search for logistics solutions more inserted in this context.

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