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Evolution of the brazilian motorcycle from 2003 to 2020: market, technology, and emission policy

Evolução da motocicleta brasileira de 2003 a 2020: mercado, tecnologia e política de emissões

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Fernando Wesley Cavalcanti de Araújo
Doctor in Mechanical Engineering
Institution: Departamento de Engenharia Mecânica, Centro de Tecnologia e Geociências, Universidade Federal de Pernambuco (DEMEC – CTG – UFPE)
Address: Av. da Arquitetura, s/n, Cidade Universitária, Recife - PE, CEP: 50740-550
E-mail: fernando.wesley@ufpe.br

Maurício Pereira Magalhães de Novaes Santos
Master in Mechanical Engineering
Institution: Departamento de Engenharia Mecânica, Centro de Tecnologia e Geociências, Universidade Federal de Pernambuco (DEMEC – CTG – UFPE)
Address: Av. da Arquitetura, s/n, Cidade Universitária, Recife - PE, CEP: 50740-550
E-mail: mauricio.novaessantos@ufpe.br

Guilherme Medeiros Soares de Andrade
Doctor in Mechanical Engineering
Institution: Departamento de Engenharia Mecânica, Centro de Tecnologia e Geociências, Universidade Federal de Pernambuco (DEMEC – CTG – UFPE)
Address: Av. da Arquitetura, s/n, Cidade Universitária, Recife - PE, CEP: 50740-550
E-mail: guilherme.soaresandrade@ufpe.br

Fábio Santana Magnani
Doctor in Mechanical Engineering
Institution: Departamento de Engenharia Mecânica, Centro de Tecnologia e Geociências, Universidade Federal de Pernambuco (DEMEC – CTG – UFPE)
Address: Av. da Arquitetura, s/n, Cidade Universitária, Recife - PE, CEP: 50740-550
E-mail: fabio.magnani@ufpe.br

ABSTRACT

Motorcycles are relevant in the Brazilian individual transportation fleet, but they are not as studied as passenger cars. In this study, it is presented a review evaluating engine and physical parameters from motorcycles from 2003 to 2020. First, it is presented the Honda sales dominance in all motorcycle segments sales. After, are presented and analyzed the

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evolution of main parameters (fleet, average price, engine capacity and maximum power, and weight) from 2003 to 2020. Finally, there is a review regarding the Brazilian motorcycle air pollution control (PROMOT), comparing it with the similar European emission program (EURO) and the Brazilian program for car (PROCONVE). It is conclued that public data for motorcycles in Brazil are far less transparent (*e.g.*, fuel economy and CO_2 emission official results are not available for the population and researches) when compared to the similar scenario for Brazilian cars. The authors suggest CONAMA to verify the positive aspects of the PROCONVE program and replicate them for PROMOT, which may foster a long-term improvement in the motorcycle fleet.

Keywords: motorcycles, PROMOT, PROCONVE, emission.

RESUMO
As motos são relevantes na frota de transporte individual brasileira, mas não são tão estudadas quanto os carros de passageiros. Neste estudo, apresenta-se uma revisão avaliando os parâmetros físicos e motores dos motociclos de 2003 a 2020. Primeiro, é apresentado o domínio de vendas Honda em todas as vendas de segmentos de motocicletas. Depois, são apresentados e analisados a evolução dos principais parâmetros (frota, preço médio, capacidade do motor e potência máxima e peso) de 2003 a 2020. Por fim, há uma revisão sobre o controle brasileiro da poluição do ar por motocicletas (PROMOT), comparando-o com o similar programa europeu de emissões (EURO) e o programa brasileiro para automóveis (PROCONVE). Conclui-se que os dados públicos para motocicletas no Brasil são muito menos transparentes (por exemplo, economia de combustível e resultados oficiais de emissão de CO2 não estão disponíveis para a população e pesquisas) quando comparados ao cenário semelhante para carros brasileiros. Os autores sugerem que a CONAMA verifique os aspectos positivos do programa PROCONVE e os replique para o PROMOT, o que pode promover uma melhoria a longo prazo na frota de motocicletas.

Palavras-chave: motocicletas, PROMOT, PROCONVE, emissão.

1 INTRODUCTION

The road passenger transportation is a relevant topic in all over the world. A high concern is dedicated to study the automobiles and the transit; the former focusing on the individual transportation and the latter on providing access to a large share of the population. Motorcycles, on the other hand, are not as studied even being the main individual transportation mode in several countries. Worldwide, motorcycles are employed to commute, to access education, for travel and entertainment, as a ride-hailing service, for ordering or delivering products. It is known that riders are more exposed and

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prone to suffer a serious injury or death from an accident, especially when compared to cars drivers (1). Giving all those possible points of view; public, media, and scholars assess motorcycles in a conflicting way.

Despite the considerable presence of these vehicles in several countries, few studies in the literature presents the evolution of the characteristics of motorcycles or evaluates and discusses how their emission and fuel economy has varied over the years. In fact, the vast majority of the studies are dedicated to accidents. Few information regarding emission are available, and it is considered that in 2008 the CO and pollutant emission (NHMC, NO_x) from one motorcycle was equivalent to six passenger cars, as the automobiles are submitted to a much stricter pollution law enforcement (2,3).

Regarding motorcycles in Brazil, for customers and researchers, it is not possible to obtain official information regarding fuel economy and emission in 2022. Despite the information being relevant for the society understand the manufacturer commitment to laws, the companies do not share those data (treated as classified), and there is not a policy from government obliging this information to be available to public, as it happens for passenger cars through the car's emission program (PROCONVE). This is relevant as fossil fuels are the main source of energy for the light-weighted vehicles and electric motorcycles were not a relevant share of vehicles sold until 2020 (4). Three-wheeled vehicles and hybrid/electric motorcycles are less than 0.14% of the total fleet in the country in that year (5).

Based on the lack of public data regarding the physical and emission characteristics for motorcycles in Brazil, the objective of this study is to discuss whether and how the Brazilian motorcycle fleet has changed in the last years with regard to their physical characteristics. Other objective of this study is to investigate and present how the motorcycle market developed along the years. It is also performed a review on the main emission policies in this period, analyzing the how the characteristics of the Brazilian motorcycle changed from 2003 to 2020, comparing them against the Brazilian policies for cars and the European policies for motorcycles. The ultimate objective of this study is to provide data for transport researchers and future public policy regarding motorcycle's emission, technology, and physical aspects.

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2 METHODOLOGY

The authors collected official information for the three most sold categories. In decreasing order: city, scooter/cub and dual-purpose. The remaining categories (*e.g.*, racing, custom) when summed are responsible for less than 5% of the sales, and were not considered. For each category, the authors selected the five most sold motorcycles yearly from 2003 to 2020. The vehicle information for those fifteen most sold models were collected from reports, models manuals, and technical websites. The average value for the parameters were sales weighted.

For each motorcycle, it was collected the price in Brazilian Reais (R$), engine capacity ($cm^3$), maximum power (hp), maximum torque (kgf.m), weight (kg), and the percentage of the fleet with flexible fuel engines and injection fuel system. The price for the vehicle was based on FIPE Table, a public chart with an estimated national average price of vehicles. Maximum power and torque were considered for the vehicles fueled with gasohol, a solution of gasoline (73% v/v) blended with anhydrous sugarcane ethanol (27% v/v).

3 RESULTS AND DISCUSSION

In the first part of this section, it is presented and discussed the supremacy of Honda in the Brazilian motorcycle market. It is relevant to present Honda because the Japanese manufacturer was the top seller in every motorcycle segment over the years. After, it is presented and discussed the evolution of the Brazilian motorcycle fleet from 2003 to 2020. This time interval was selected for this study because contains trustworthy data from national sales databanks.

3.1 ANALYSIS OF THE BRAZILIAN MOTORCYCLE MARKET: THE DOMINANCE OF HONDA

Honda was the sales leader in all the motorcycle categories, every year. Honda's story in Brazil is related to Manaus Free Trade Zone (MFTZ). MFTZ was designed as an economic area in 1957 and started up in 1967. This region was selected to promote industrialization in the region. Under an import substitution industrialization (ISI) regime

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model, the tax-incentive at the federal level could be up to 80% over inputs to be manufactured, among other benefits (6). For the companies, Manaus was attractive for the companies both for the tax regime and because of the Brazilian economic growth (7).

Honda had started its abroad (*i.e.*, outside Japan) motorcycle assembling in late 1960's in Thailand, exporting and selling to Brazil. In 1975, at the peak of the ISI policy, the government prohibited motorcycle importation, forcing the Honda and Yamaha to initiate manufacturing activities in Brazil. In 1977, Honda installed a factory in MFTZ, while Yamaha concentrated its operations in São Paulo until 1985, when transferred part of its operations to Manaus (6). Honda planned and developed a plant in the MFTZ and in 1977 produced around 79% of the motorcycles sold in Brazil that year. The dominance of Honda in the Brazilian motorcycle market has not changed ever since (7). Honda supremacy maintained and the company manufactured at least 70% of the Brazilian motorcycles sold every year since 2003, and 82% of the motorcycles sold in the 2020. In the second sales number position is Yamaha, comprising 18.5% of the total sales (8). The ratio between the number of motorcycles sold by Honda and Yamaha is in average 6.3.

The Yamaha's share in the Brazilian Market varied between 11% and 14% over the years. When Honda market share decreased, it was caused by another brand. For example, from 2003 to 2009, the Suzuki Intruder 125 model was the fourth most sold motorcycle. The others' category present in Figure 1 comprises all the other sales by companies aside Honda and Yamaha: (e.g., Shineray, BMW, Kawasaki, Suzuki, Triumph, and the others). For comparison, in 2020 in the third sales position was BMW, with just 1.1 % of the total share.

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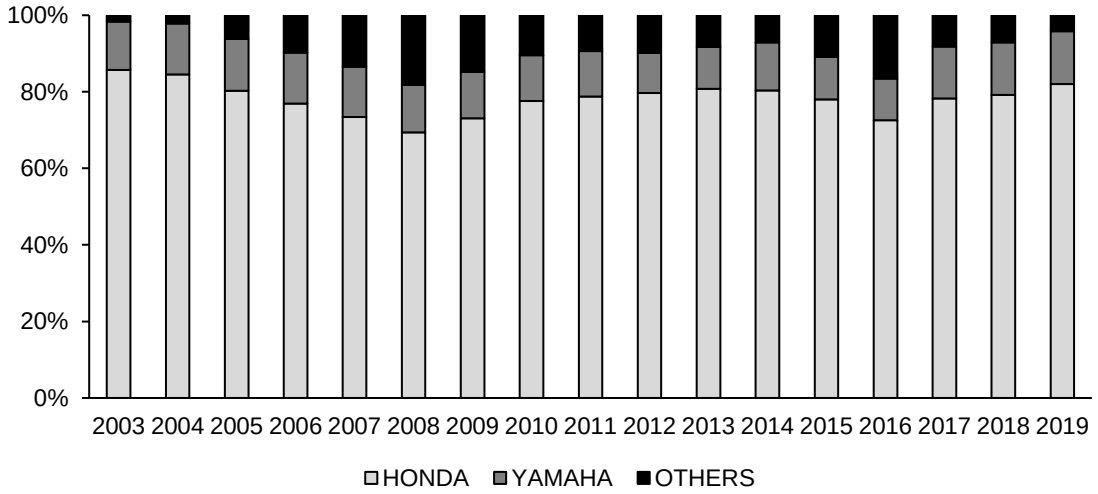
Figure 1: Honda, Yamaha, and others manufacturers in the Brazilian motorcycle sales share



Examining the companies' share in the three motorcycles' categories, in the City category (urban motorcycles with engine capacity up to 250 cm³) Honda sold 77% in 2020. In this category, Honda in 2003 had three motorcycles: CG 125, CG 150, and Twister 250. In 2015, there was a change in which the CG 150 was replaced by CG 160. In this category, a Honda's model always was the top seller. The model varied along the years: CG 125 in 2003, 2009 and 2010, the CG 150 from 2004 to 2008 and 2011 to 2015, and the CG 160 was the most sold from 2016 to 2020.

The most sold vehicle in the Scooters/Cubs category in Brazil in 2020 was the Cub Honda Biz (139,485 units) with a 110/125 cm³ engine. Honda was responsible of 86.7% of the sales in this category, with Honda Biz, Honda Pop 110, Honda PCX 150, Honda Elite 125, Honda ADV 150, and Honda SH 150. The Honda's supremacy in this category is so extreme, that in 2020, four models from Honda were ranked the most sold from first to fourth.

Dual-purpose are the third category most sold overall, presenting motorcycles similar to the City category; however, those motorcycles present reinforced suspension and characteristics that allow them to be used both in urban and in rural areas. The most sold Dual-purpose in 2020 was Honda NXR160 (101,177 units), using the same 160 cm³ displacement engine as the Honda CG 160. Honda, once again, was the most sold brand,

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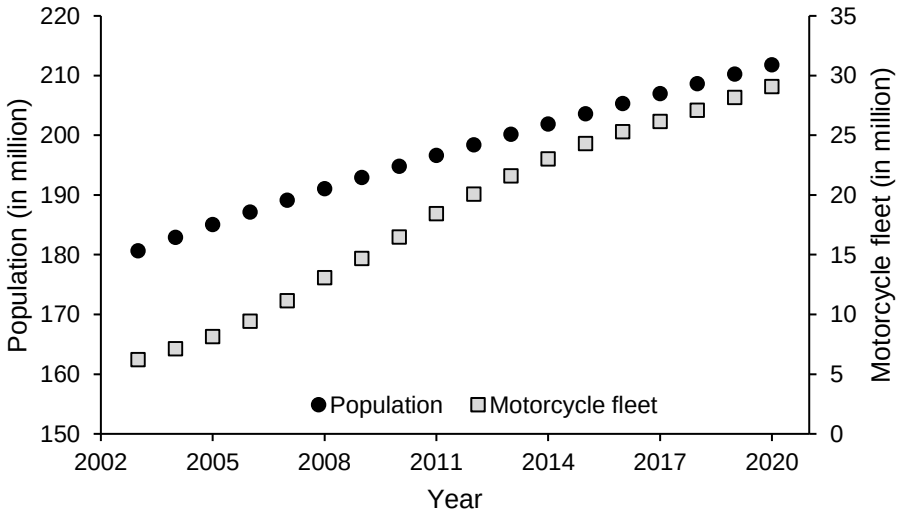
with 75.2%. The only competition in this category is against the Yamaha XTZ 150 and Yamaha XTZ 250.

3.2 BRAZIL MOTORCYCLE'S FLEET EVOLUTION FROM 2003 TO 2020

The Brazilian population and the motorcycle fleet increased in the last years. From 2003 to 2020, the motorcycles fleet increased from 6.1 to 29.1 million (377%) while the population increased from 174 to 210 million of inhabitants (21%), Figure 2. In order to compare the number of motorcycles in Brazil against other countries, a variable will be introduced: vpti (motorized two- and three- wheeled vehicles per 1,000 inhabitants). Considering three-wheeled vehicles do not change the Brazilian status, but allows comparison with Asian countries. In Brazil, vpti has increased from approximately 34 to 137, from 2003 to 2020(5). Vpti had doubled in six years from 2003 to 2009, and doubled again from 2009 to 2020.

Figure 2: Brazilian fleet of motorcycles (DENATRAN, 2019)



Brazil can be fit in a group composed by other middle-income countries that present favorable conditions (*e.g.*, climate, financial) to the acquisition of motorcycles: Argentina (133), Colombia (106), Iran (133), India (92). The number within parenthesis refer to vpti in 2015 (9). High-income countries present lower vpti: USA (26), Canada (18), United Kingdom (19), Denmark (35), Germany (48). There is another group in

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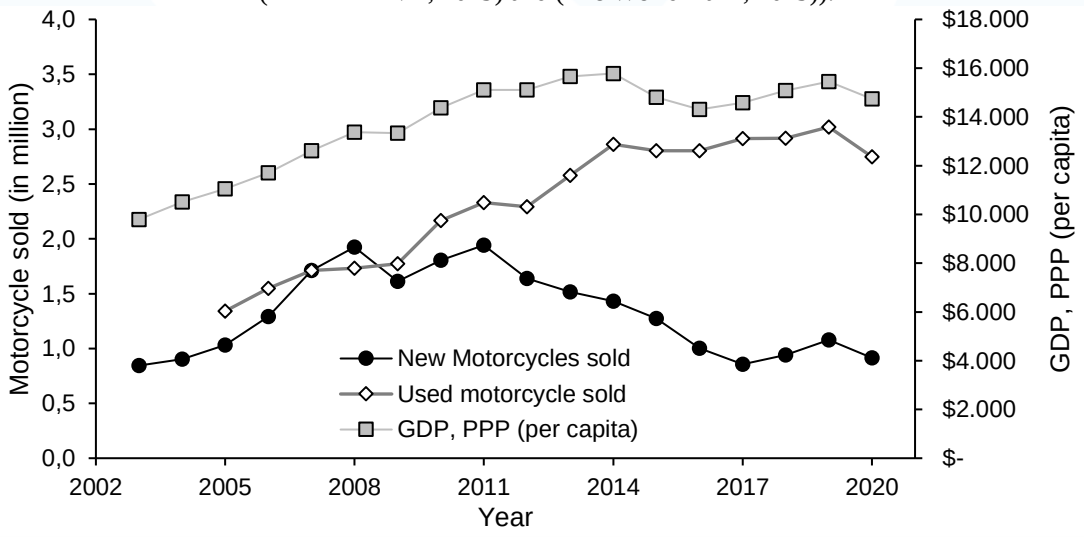
which the main transportation mode is 2-wheeled (including 3-wheeled vehicles), composed by Thailand (286), Indonesia (345), and Vietnam (421). Cultural and regional characteristics influence this variable, as for instance Italy is a high-income country but presents 147 vpti, higher than several middle-income countries. Nevertheless, middle-income countries as Egypt (23), Mexico (13), and South Africa (7) that present vpti lesser than high-income countries.

The reason to the acquisition of a new individual vehicle could be the increased average income (10). To verify if there is a correlation among these variables, it was selected the Gross Domestic Product per capita adjusted considering the Purchasing Power Parity (GDP,PPP) to represent the standard of living and economic output of a country (The World Bank, 2019). A low Pearson's correlation coefficient (R = 0.29) was obtained when comparing the GDP,PPP per capita to the number of new motorcycles sold yearly. When comparing the GDP,PPP to the sales of used motorcycles, it was obtained a high Pearson's coefficient (R = 0.87) implying that the sales of used motorcycles can be related to the overall income's increase.

Figure 3: Annual registration of vehicles in Brazil and GDP PPP per capita. (Adapted from (FENABRAVE, 2019) and (The World Bank, 2019)).



The selling of new motorcycles may not be completely correlated to GDP,PPP because the wage distribution is not uniform. From 2012 on, the non-increase in the

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overall GDP, PPP per capita may have affected the sales of new motorcycles, decreasing from 1.94 million in 2011 to 0.85 million in 2017. In this period, the number of used motorcycles sold had increased from 2.3 to 2.9 million. In developing countries, the rider usually do not desire to be dependent of public transportation; and owing an vehicle can provide mobility both in a highly congested city and rural areas unattended by the public transportation. Additionally, in several cities the public transportation is not considered punctual and comfortable (12) Motorcycles are also associated to a lower fuel consumption and maintenance costs. Their need of a small space for storage and parking are also factors that contribute to its acquisition (13).

3.2.1 Annual average price

In Figure 4, the actual price is the informed in FIPE Table to acquire a new vehicle, whereas the corrected price is the currency that a customer would have in December 2020 if instead of buying, invested the money employing the Brazilian customer price index (IPCA). The IPCA index has varied in average 5.75% per year along the studied years, but presented a maximum 10.7% yearly rate in 2015. The average actual buying price in Brazilian Reais (R$) for motorcycles has increased 166% from R$ 5,035.65 to R$ 13,372.90 in the last 17 years. However, this price movement has not sustained when considering the inflation, as the corrected price has decreased 16% during the same time.

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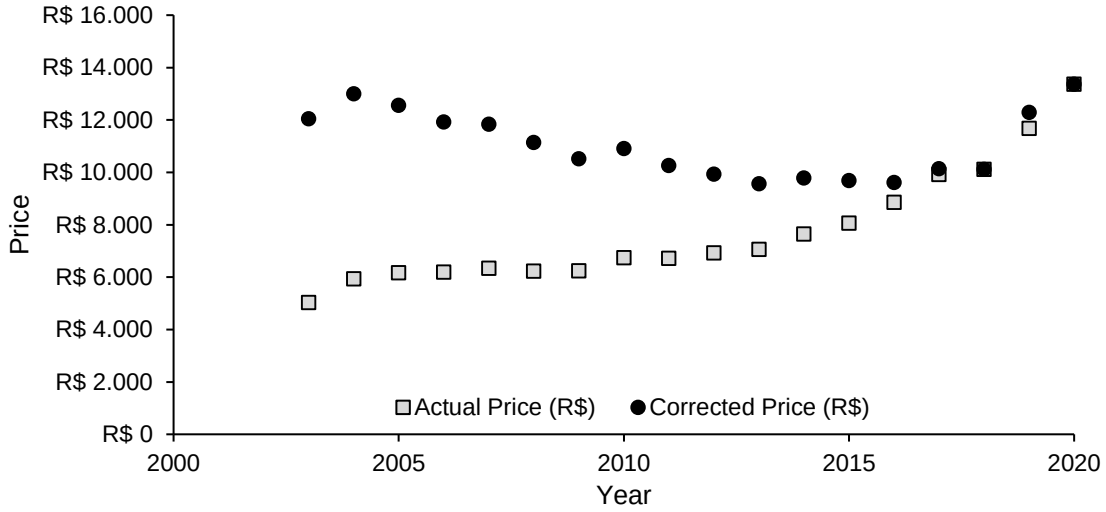
Figure 4: Average price for Brazilian motorcycles.



When comparing the actual price with the GDP,PPP per capita it is perceivable that the new motorcycle has become much more expensive for the consumer, especially from 2017 to 2020. From 2008 to 2013 the ratio between the Average Price/GDP,PPP was the lowest, contributing to the acquisition of brand new motorcycles, and the further increase in the sales of used motorcycles in detriment of purchasing new ones.

According to ABRACICLO (2022), the motorcycle's average basic composition is made up from carbon steel (56.3%), aluminum (19.1%), plastic (7.4%), copper (5%), rubber (4.6%), among others. The main components are commodities, whose price are defined by worldwide supply and demand chain. The price of commodities is both influenced by their international demand, and from the Brazilian Real/US Dollar parity. When evaluating the correlation among the main items in the motorcycle production with motorcycle price, it was found for the Iron Ore Price (US$/ton) a correlation of R=0.16, for the Aluminum (US$/ton) a correlation of R=-0.14, and for the currencies (US$/R$) a high correlation of R=0.85. It is implied that the main responsible for the price variation is the devaluation of Brazilian currency, not the price of the major elements employed in the manufacturing process.

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3.2.2 Engine capacity and average maximum power

Along the studied years, all motorcycle sold in Brazil had a four-stroke engine equipped. The sales of two-stroke engine were discontinued in late 90s partially by manufacturers' choice, partially by the public notice on the two-stroke characteristic issues on fuel/oil consumption, emission, and performance. The last two-stroke engine motorcycle sold was Yamaha DT 200 in 2000, an improvement from a project originally released in 1981 (14)

The average engine capacity increased from 130 cm^3 to 145 cm^3 from 2003 to 2020 (Figure 5). This pattern happened in the three categories. In the Figure 5 it is possible to verify that 2003, 2009, and 2015 present discontinuities as the 125 cm^3 model were the most sold overall. Considering the engine capacity from 2003 to 2018, there was an increase of 19% in the engine capacity. The increase of the average engine capacity from 2015 to 2019, can be explained by the retirement of the Honda's 150 cm^3 models: CG 150 and NXR150. They were replaced by the CG 160 and NXR160. In 2020, there was a decrease in the average engine capacity as COVID pandemic may have affected the sales. Cheaper motorcycles are usually purchased by citizens that had income affected; on the other hand, there was an increase in the number of workers dedicated to deliver goods that probably purchased a used motorcycle. Before the pandemic, the delivering of goods and foods by motorcycle was in expansion. The pandemic expanded this job position and is estimated that more than 4 million of workers delivering products, and can be considered as one of the most popular jobs in Brazil (15).

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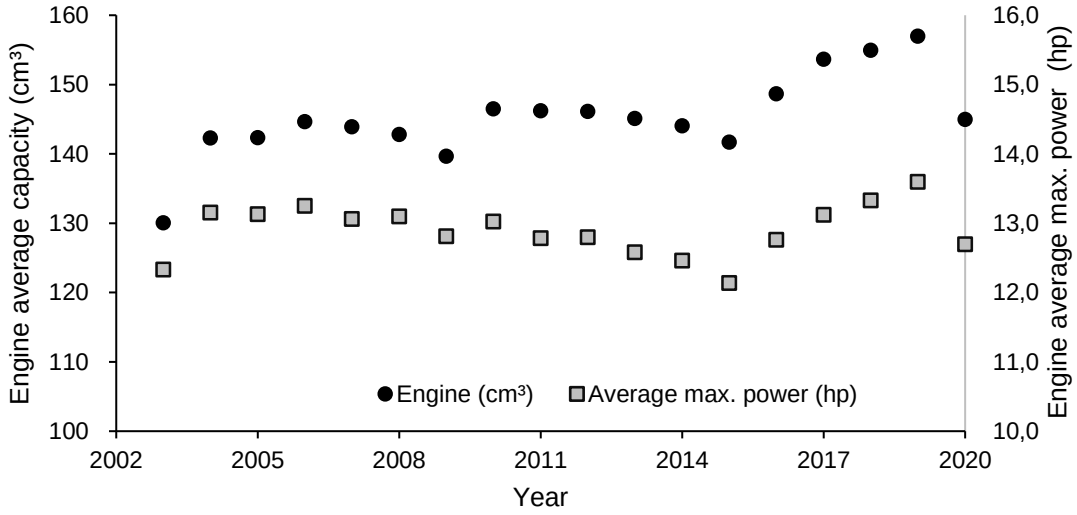
Figure 5: Average engine capacity and maximum power for Brazilian motorcycle fleet



The average maximum power curve has increased 5.8% (from 12.0 hp in 2003 to 12.7 hp in 2020). Although the maximum power developed by the engine can be visually related to the engine capacity, a moderate correlation was found (R = 0.63). The average maximum power of the fleet is lesser than the (most sold) CG 160 as considers the 125cm³ models (and scooters/cub), at the same time does not consider the most expensive models equipped with more powerful engines. Honda Biz engine, the most sold in the scooter/cub category in 2020 had 8 hp as maximum power, while CG 160 engine had a maximum power of 14.7 hp.

To evaluate if the engines had become more powerful for the same capacity, it was employed the specific power (ratio between the maximum power and the engine capacity). The average specific power has decreased 9%, from 0.096 hp/cm³ in 2003 to 0.088 hp/cm³ in 2020.

Regarding electronic injection and flex-fuel engines, notably in 2003 all motorcycles contained carburetors. The electronic injection system nowadays encompasses all models, fully replacing the use of carburetors. The change from carburetors to electronic injections happened to achieve the emission targets described in PROMOT 3, released in 2009, although they were initially not obliged to change. The flex-fuel engine technology in Brazilian motorcycles has started only in 2009 with Honda CG 150 Titan Mix, six years later than cars (Business, 2019). The flex-fuel share has

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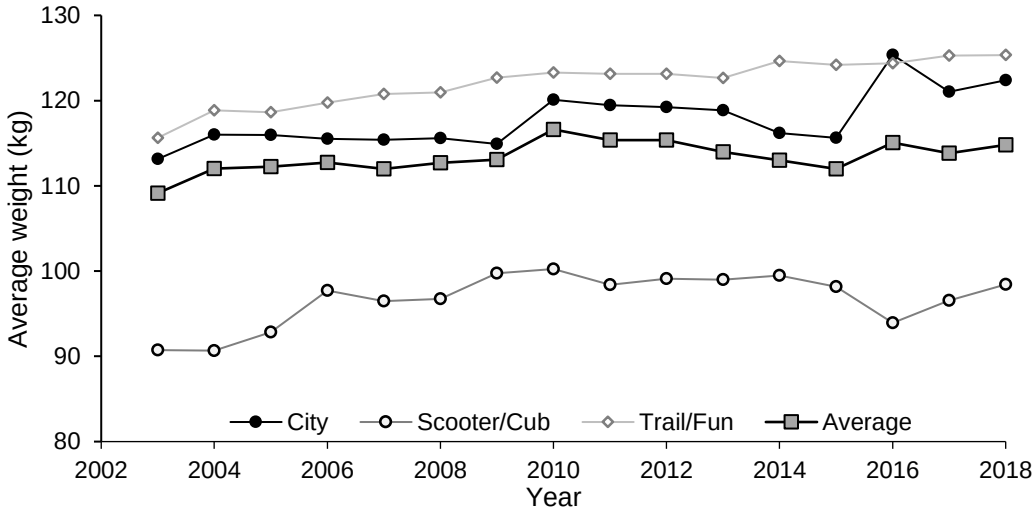
steadily increased in the last 11 years, as of 2020 only 16% of the motorcycles marketed did not have a flex fuel engine.

Complementing, for the motorcycles in 2020 the average engine speed for the maximum power was at 7,101 rpm, while the maximum torque was found at 5,178 rpm. The relevance of data as engine capacity and maximum power is relevant for evaluation of driving cycles, focusing on evaluating emission and consumption in a fleet (16,17).

3.2.3 Average weight

The average weight (Figure 6) was always between 105 to 120 kg. The lightest motorcycle in 2020 was Honda Pop 110, weighting 87 kg. The heaviest motorcycle considered was Honda XRE300, 144 kg. The substitution of carburetor to electronic injection has increased the cost of motorcycles, but in general provided a slight decrease in the weight. For Honda Biz 125, the 2006's lightest and heaviest version weighted 98.7 kg and 101.9 kg, equipped with carburetors. The 2009's Honda Biz changed the carburetor to electronic injection and lightest and heaviest version weighted 98.0 kg and 101.0 kg, less than 1kg. For the Honda CG150, both lightest versions similarly decreased the weight when changing from carburetor (2007) to electronic injection (2009); however, the motorcycle's design and dimensions had changed as well.

Figure 6: Average weight for the Brazilian motorcycle fleet



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4 REVIEW OF THE BRAZILIAN EMISSION POLICY FOR MOTORCYCLES

This section is divided in three topics. In the first topic, the authors discuss PROMOT. After, PROMOT is compared to the similar European air control program. The final section compares PROCONVE to PROMOT.

4.1 PROMOT

PROMOT was created by CONAMA to contribute to the reduction of air pollution through the establishment of emissions' limits, deciding, and requesting technological advances. CONAMA is responsible for organizing the standards of the type-approval tests, providing certification for the prototypes and projects developed by the local manufacturers and importers, and other related activities (18).

PROMOT has defined five phases so far, from M1 to M5 sequentially. The program was launched in 2002 when it was established M1 and M2 (IBAMA Directive No. 17/2002, CONAMA Resolution No. 297/2002). Before the phase M1, there was no emission control regulation for any two-wheeled vehicle marketed in Brazil. Thus, this was an important step to establish a culture regarding emission control. The second phase (M2) reduced the emission limits in 83% for CO and 60% for HC + NO_x. Table 1 describes the phase, vehicles category, and emission limits. CONAMA define mopeds as two-wheeled vehicles whose engine displacement is less than 50 cm^3 and capable of achieving a maximum speed less than 50 km/h.

The phase M3 was published in the CONAMA Resolution No. 342/2003 for all vehicles in production from 2009. In this phase, the data regarding the emission of CO_2 was requested to be reported to the government, to keep track of the overall emissions; however, greenhouse gases and fuel consumption were still unregulated.

Table 1: Emission limits for mopeds and motorcycle for PROMOT phases M1, M2, and M3 (IBAMA, 2019)

Phase	Year	Vehicle category	Engine capacity (cm^3)	CO (g/km)	HC+NO_x (g/km)	HC (g/km)	NO_x (g/km)	CO_{idle} (%)
		Mopeds		6.0	3.0			
M1	2003 – 2005	Motorcycle	≤ 250 cm^3	13		3.0	0.3	6.0%
		Motorcycle	> 250 cm^3	13		3.0	0.3	4.5%
M2	2005 – 2008	Mopeds		1.0	1.2			

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		Motorcycle	≤ 150 cm³	5.5	1.2	0.3	
		Motorcycle	> 150 cm³	5.5	1.0	0.3	
		Mopeds		1.0	0.8	0.15	
M3	2009 – 2014	Motorcycle	≤ 150 cm³	2.0	0.8	0.15	
		Motorcycle	> 150 cm³	2.0	0.3	0.15	
		Mopeds		1.0	0.8	0.15	Report
	2014[1]	Motorcycles	< 130 km/h	2.0	0.8	0.15	
M4		Motorcycles	≥ 130 km/h	2.0	0.3	0.15	
	2016	All vehicles	< 130 km/h	2.0	0.56	0.13	Report
		All vehicles	≥ 130 km/h	2.0	0.25	0.17	Report

[1] – the limits are applied for new projects

In the three first phases of PROMOT, the manufacturers complied with the test method and pollutants' measurement procedure provided by European Community Directive No 97/24/EEC. In 2011, CONAMA set a new phase (M4, CONAMA resolution No. 432/2011) with requests established in 2014 and in 2016 (Table 1). A relevant change between M3 and M4 was that the vehicles started to be evaluated based on their maximum speed, instead of their engine capacity. Another relevant modification was also the adoption of a new test procedure using Worldwide Motorcycle Test Cycle (WMTC), complying with the pattern adopted in Euro 4, released years later.

PROMOT M4 and M5 present two different dates in their tables; the first date dedicated for the new projects, whereas older vehicles can still be sold, even if they were not complying with the actual emission targets. In the second date, 2016 for PROMOT M4, all new vehicles sold should fully comply with the regulation. For PROMOT M4, the dates were 2014 and 2016. PROMOT Phase M5 will be applied in 2023 and 2025 (CONAMA Resolution No. 493/2019) and will indistinctly consider mopeds, motorcycles, tricycles, and quadricycles. For 2023, in addition to the CO, HC, and NO_X, the companies should also measure the non-methane hydrocarbon (NMHC), particulate material (PM), and aldehyde in a dynamometer test. Table 2 summarizes the emission requirements for the type-approval test using the driving cycle, and Table 4 presents the emission limits for the emission in idle engine speed and engine speed above 2,000 rpm.

Table 2: Emission limits for PROMOT phase M5 in the dynameter test and idling speed

Year	**Vehicles**	**CO (mg/km)**	**HC[1] (mg/km)**	**NMHC (mg/km)**	**NO_x (mg/km)**	**PM[2] (mg/km)**	**Aldehyde (mg/km)**	**CO_2**
2023	New projects	1,000	100	68	60	4.5	20 or 30[3]	Inform

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2025	All vehicles	1,000	100	68	60	4.5	20	Inform

Year	**Vehicles**	**CO_{idle} (ppm)**	**CO_{idle} (ppm)**	**HC_{idle}[4] (ppm)**
2023	New vehicles	5,000	3,000	50
2025	All vehicles	5,000	3,000	50

1 – Limit for vehicles using natural gas as fuel.
2 – Limit for vehicles with fuel direct injection.
3 – Limit for motorcycles with maximum speed higher than 130 km/h.
4 – Value in hexane equivalent.

Other addition in PROMOT M5 is the mandatory OBD diagnostic of the engine emission system. There are different OBD standards to applied over the years, as OBD M1 is to be applied from 2023, and OBD M2, capable of gathering more information, is mandatory from 2025 for the new vehicles and 2027 to all vehicles. The OBD requirements are expected to be the same of the European legislation, although concessions could consider local conditions (19). Other relevant advance is regarding the evaporative emissions, that was established in Phase M4 considering only the "hot" regime condition, in the Phase M5 will consider the "cold" and "hot" regime.

4.2 COMPARISON BETWEEN PROMOT AND EURO STANDARDS FOR MOTORCYCLES

Europe has started monitoring and regulating air pollution from cars in the 70's (Council Directive No 70/220/EEC (20), and from heavy duty vehicles in 1988. In Europe there is a complex picture regarding motorcycle regulation. There are diverse types of motorcycles (<50cm³ to >1000cm³), driving patterns (commuting or leisure), differences across countries (North or South) and season (winter, summer). An effective program should consider those diversity (21).

The motorcycle's legislation regarding emissions has started with the adoption of the UN-ECE regulation 40 (motorcycles) and 47 (mopeds), followed by the "multi-directive" Directive 97/24/EEC. The European directive restricted the emission limits compared to the UN-ECE regulation in up to 74% in the strictest scenario. Measurement of HC and NO_x were already considered (21). The Directive 97/24/EEC was applied for new motorcycles projects from 1999, and all projects from 2003 on.

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The three first phases of Euro Standards for motorcycles present limits and regulations equivalent to PROMOT, but the Brazilian and European phases were not adopted concomitantly. When Brazil adopted the first phase (M1) in 2003, Europe was about to change their set of rules to EURO 2 in 2004. Brazil updated their regulation in 2006 to phase M2, whereas the European Union was adopting the Euro 3 standards, later adopted by Brazil in 2009.

While the first three Brazilian standards were similar to the Europeans, the Euro 4 standards presented stricter emission limits when compared to PROMOT M4. Additionally, the European Regulation was more complex as, for instance, it considered seven categories of vehicles. It also considered whether the vehicle is propelled by spark/compression ignition, hybrid engines; and the type of fuel. In the Brazilian law, only two categories were considered: mopeds and others. They were fueled as recommended by its manufacturer in the owner's manual.

4.3 DISCUSSION REGARDING THE BRAZILIAN EMISSION PROGRAM FOR CARS AND MOTORCYCLES

A relevant and detailed review regarding the creation of PROCONVE and its evolution is presented in Mendes (2004). In 1976, CONTRAN Resolution Nº 507 established the control of emission of gases and vapors from crankcases. In the same year, The São Paulo Government published the Law Nº 997 monitoring smoke emission from new diesel vehicles, allowing the sales of those approved in the emission tests. In 1977 started a discussion of a national emission control program, and CETESB promoted events to discuss the air pollution that was steadily increasing in São Paulo. In 1981, it was elaborated the ABNT NBR 6601, applied to measure the emission of light vehicles.

After several years of discussion, CONAMA created PROCONVE in 1986 targeting the control and reduction of emission for light/heavy vehicles (Resolution Nº18/1986). The pollutant initially measured were CO, PM, SO_2, NO_2, HC, and O_3. According to Mendes (2004), it was not considered necessary to apply the emission control for motorcycles in that moment, as they were considered to globally contribute far less when compared to other vehicles. In addition, the decision of not monitoring

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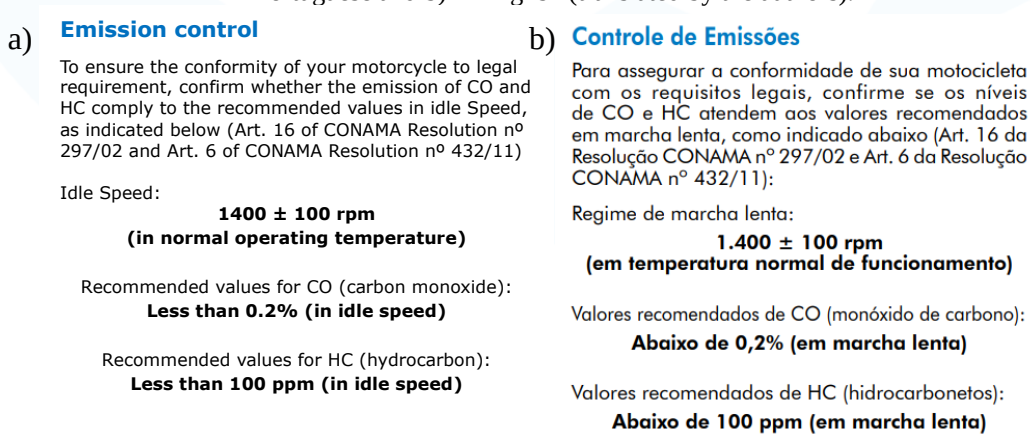
motorcycles avoided an extra cost. By 1994, there was rules to measure the pollutant emission in heavy vehicles. As previous presented, the first regulation for motorcycles was presented only in 2002 as the general scenario of transportation had changed (23).

One relevant difference between the program for car and motorcycle is the pollutant measured. PROMOT only inserted it in phase its M4, as it was an obligation for the manufacturer. They should inform the values of emission of CO, HC, and the engine speed in idle speed in the owner's manual. Figure 8 presents an example of the description in owner's manual from the most sold motorcycle in 2019, Honda CG 160. The original text is written in Portuguese; however, a translation to English performed by the authors is placed aside. The original text present in the owner's manual says that the vehicle complies to the limits of CO emission "less than 0.2% (in idle speed)", whereas for the hydrocarbon is "less than 100 ppm (in idle speed)". Although these values are important to be informed, and are within the established limits, this information is overall useless. If the vehicles were not accomplishing the law, they could not be marketed. Actually, the official values for gases emissions in the dynamometric test are only reported to the government, and can be not be accessed by the society or researchers.

Figure 7: Emission control section from the manual's owner of motorcycle Honda CG 160, 2019 a) in Portuguese and b) in English (translated by the authors).


a)

Emission control

To ensure the conformity of your motorcycle to legal requirement, confirm whether the emission of CO and HC comply to the recommended values in idle Speed, as indicated below (Art. 16 of CONAMA Resolution nº 297/02 and Art. 6 of CONAMA Resolution nº 432/11)

Idle Speed:

1400 ± 100 rpm
(in normal operating temperature)

Recommended values for CO (carbon monoxide):
Less than 0.2% (in idle speed)

Recommended values for HC (hydrocarbon):
Less than 100 ppm (in idle speed)

b)

Controle de Emissões

Para assegurar a conformidade de sua motocicleta com os requisitos legais, confirme se os níveis de CO e HC atendem aos valores recomendados em marcha lenta, como indicado abaixo (Art. 16 da Resolução CONAMA nº 297/02 e Art. 6 da Resolução CONAMA nº 432/11):

Regime de marcha lenta:

1.400 ± 100 rpm
(em temperatura normal de funcionamento)

Valores recomendados de CO (monóxido de carbono):
Abaixo de 0,2% (em marcha lenta)

Valores recomendados de HC (hidrocarbonetos):
Abaixo de 100 ppm (em marcha lenta)

PROCONVE presented different policies in the last fifteen years. In 2013, to receive a tax exemption, the automakers should submit their models to a standardized test

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to measure the fuel economy and emissions (PBEV). If the manufacturer desired, the results were displayed on a label attached to the vehicle. However, even if the manufacturer did not attach the label, it was possible to verify the results in the INMETRO official website, also indicating how the vehicle compare to others in its category. PBEV program is considered important and needed to improve the energy efficiency of the fleet, provided a standardized information for the customers, and encouraged concurrence to improve the vehicle's energy efficiency. Nowadays the CO_2 emission and fuel economy are available for the entirety of the passenger cars sold in Brazil. For motorcycles there are no official public results for these metrics regarding the driving standardized test, and are poorly informed in the idle speed test.

In 2019, the Brazilian government launched a new program for passenger cars, Rota 2030. The new program has mandatory energy efficiency targets for national and imported vehicles. The companies that do not improve 11% in the energy efficiency will still be able to sell the vehicle, although it will have to pay a fine. In addition, if the company improve their efficiency better than the highest target of the program, the manufacturer will receive an additional tax discount. The Rota 2030 program also provide tax reductions for electric and hybrid vehicles, incentive for research and development, and considers the regulations provided by the World Trade Organization.

5 CONCLUSION

In this study, Honda was presented as the main Brazilian manufacturer and its evolution in Brazilian motorcycle market. It was also presented and evaluated the main characteristics (price, engine capacity, maximum power, weight) from the Brazilian motorcycle fleet from 2003 to 2020. Results from this study may be employed to in transportation researches, vehicle simulations, or used in the development of new public policies. The actual price has only increased over the years, but the corrected price (considering inflation) has not followed the same pattern. It was found that the motorcycle price is highly correlated to USD dollar (R = 0.85). The engine capacity has increased 11%, and the average maximum power has increased 5.8% in the same period. The

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entirety of Brazilian motorcycle presents electronic injection, and the majority (>84%) has flex fuel engines. The average weight has increased 14%.

The scenario of the PROMOT was presented and compared with the European legislation and with PROCONVE. In general, the PROMOT legislation is considered responsible to provide stricter emission parameters and is an important step to promote the culture to improve emission results. As another positive aspect, the PROMOT parameters were based to the Europeans ones, verifying relevant and modern aspects worldwide. However, as a relevant drawback for the customers, researchers and society, there are no public available information regarding emission for motorcycles.

Therefore, authors conclude that the emissions policy should be more transparent. It also must continue to be constantly updated in accordance to what is happening worldwide. PROMOT program should verify the positive points present in the PROCONVE program, such as the labelling program (PBEV), in which after submitting the car to a standard procedure, the results are broadly available for society, allowing the consumer to compare the fuel economy and emission results to other vehicles overall and in the same category. Applying those steps in its forthcoming PROMOT phases could benefit the society and also promote competition among the companies as it happened for passenger cars.

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GLOSSARY

ANFAVEA - Brazilian National Association of Vehicle Manufacturers (in Portuguese: Associação Nacional dos Fabricantes de Veículos Automotores)

CETESB - Brazilian Environmental Sanitation Technology Company in Portuguese: Companhia de Tecnologia de Saneamento Ambiental de Brasil)

CONAMA - National Environment Council (in Portuguese: Conselho Nacional do Meio Ambiente)

CONTRAN – National Transit Council (in Portuguese: Conselho Nacional de Trânsito)

FIPE - The Institute of Economic Research Foundation (in Portuguese: Fundação Instituto de Pesquisas Econômicas)

IBGE - The Brazilian Institute of Geography and Statistics (in Portuguese: Instituto Brasileiro de Geografia e Estatística)

IPCA – Customer Price Index (in Portuguese: Índice Nacional de Preços ao Consumidor Amplo)

NMHC – Nonmethane Hydrocarbon

PBEV – Brazilian Vehicle Labelling Program (In Portuguese: Programa Brasileiro de Etiquetagem Veícular)

PROCONVE - Motor Vehicles Air Pollution Control Program (in Portuguese: Programa de Controle da Poluição do Ar por Veículos Automotores)

PROMOT - Program for Control of Air Pollution from Motorcycles and Similar Vehicles (in Portuguese: Programa de Controle da Poluição do Ar por Motociclos e Veículos Similares)