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Evolution of air quality as a function of vehicle demand in the Metropolitan District of Quito

Evolución de la calidad de aire en función de la demanda vehicular en el Distrito Metropolitano Quito

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Abstract

Currently, the negative effects of air pollution on public health and the environment is a challenge of interest to the international community, which has focused much of its efforts and resources on policies, agreements and programs aimed at improving air quality. In this context, the present study determines a correlation between vehicle demand and air pollution levels in the Metropolitan District of Quito DMQ. The development of this study implements a quantitative research methodology that includes the collection and analysis of data relevant to the objectives. Despite being on the agenda of the DMQ government for the last 25 years, with CORPAIRE and the Metropolitan Corporation for the Integral Management of Solid Waste and Environmental Protection of Quito as its governing, monitoring and control bodies, the deficient mitigation of air pollution continues to threaten public health, local ecosystems and biodiversity.

Keywords: Air pollution, vehicular demand, Metropolitan District of Quito, greenhouse gases, environmental policies

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Resumen

En la actualidad, los efectos negativos de la contaminación del aire sobre la salud pública y el medio ambiente es un desafío de interés para la comunidad internacional, misma que ha enfocado gran parte de sus esfuerzos y recursos en políticas, acuerdos y programas enfocados en mejorar la calidad del aire. En este contexto, el presente estudio determina una correlación entre la demanda vehicular y los niveles de contaminación del aire en el Distrito Metropolitano de Quito DMQ. El desarrollo del presente estudio implementa una metodología de investigación cuantitativa que abarca la recopilación y análisis de datos relevantes para los objetivos planteados. A pesar de encontrarse en la agenda de interés del gobierno del DMQ durante los últimos 25 años, con la CORPAIRE, y la Corporación Metropolitana de Gestión Integral de Residuos Sólidos y Protección del Medio Ambiente de Quito como sus órganos rectores, de monitoreo y control, la deficiente mitigación de la contaminación del aire continúa amenazando a la salud pública, a los ecosistemas locales y a la biodiversidad.

Palabras clave: Contaminación del aire, demanda vehicular, Distrito Metropolitano de Quito, gases de efecto invernadero, políticas ambientales

Introduction

The International Community has evidenced several efforts to mitigate air pollution through agreements, programs and policies, being even part of 2 of the 17 goals of the 2030 Agenda for Sustainable Development of the United Nations, SDG 3 regarding Health and Well-being, and SDG 11 regarding Sustainable Cities and Communities (UN, 2024). According to the International Energy Agency (IEA, 2023), approximately 24% of CO2 emissions come from the transport sector, which raises this sector as a target of public policies for the reduction of emissions in favor of the improvement of air quality according to. (United Nations, 2015).

Cities around the world face the challenge of air pollution, a problem that negatively affects public health and the environment. In the Metropolitan District of Quito (DMQ), air quality is particularly affected by vehicle emissions, especially during peak traffic hours.

This study analyzed the evolution of air quality in the DMQ as a function of vehicle demand and the incidence of the corpaire. For this purpose, historical data on air quality and vehicle demand were analyzed using statistical and modeling tools to identify patterns and relationships between the two variables.

The research focused on aspects of air quality analysis, evaluating the levels of atmospheric pollutants such as particulate matter (PM10 and PM2.5), carbon monoxide (CO) and ozone (O3) in the DMQ; also an analysis of vehicle demand by studying the increase of vehicles over two decades within the DMQ, before and after the creation of the corpaire; and finally a relationship between air quality and vehicle demand by establishing a correlation between air quality data and vehicle demand to identify how variations in the number and type of vehicles influence pollutant levels.

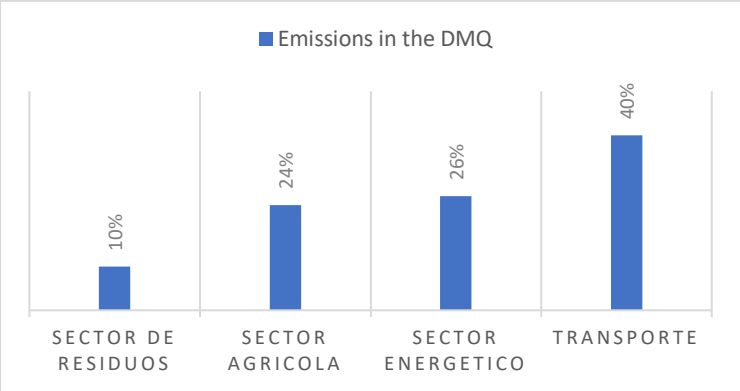
We will investigate how CO2 pollution in the DMQ has changed over time by identifying the key factors that have contributed to these variations. We will examine how the increase in the number of vehicles in Quito has affected pollution levels, analyzing both CO2 emissions and other pollutants. The impact of CORPAIRE will be studied by evaluating whether strategies and policies implemented to mitigate pollution.

Air quality in cities is an issue of growing importance due to its implications for public health and the environment. In the Metropolitan District of Quito (DMQ), air pollution has been a constant concern, exacerbated by the increase in the number of vehicles and industrial activities. This study focuses on analyzing the evolution of air quality in the DMQ and the impact of the Corporation for the Improvement of Air Quality in the DMQ (CORPAIRE) in this process.

Air quality and greenhouse gas (GHG) emissions have grown significantly in recent decades. Several studies have highlighted the importance of monitoring and managing CO2 emissions to mitigate climate change and improve public health (COMMERCE, 2015). According to Quito's Secretariat of Environment, in recent years, the city has emitted millions of tons of CO2, with the transport sector contributing a significant portion of these emissions. In more recent years, vehicles have emitted millions of tons of CO2, highlighting the significant impact of transportation on Quito's carbon footprint.

It is the composition of the air and its suitability for certain applications, indicating the cleanliness or purity of the air we breathe. Good quality air has low levels of pollutants, such as particulate matter and harmful gases, from (HOLCIM, 2024). It refers to airborne particles such as gases (sulfur dioxide, nitrogen oxides, carbon monoxide and ozone) and volatile organic compounds (VOCs). (DKV Insurance, 2024).

Figure 1 . Emissions in the DMQ 2015



Note: Developed by the authors, data obtained from (La Hora Newspaper, 2023)

Carbon Footprint (CF):

The total amount of GHG emitted by human activities, expressed in tons of CO2 equivalent.

The Carbon Footprint theory is based on the quantification of GHG emissions associated with human activities. This metric is used to evaluate the environmental impact of a city, company or individual. In the case of Quito, the CoC has been used to identify the main sources of CO2 emissions and to develop mitigation strategies (Ministry of the Environment, 2017)..

Air Quality Index (AQI):

The Air Quality Index (AQI) is another important model used to measure and communicate air quality. This index takes into account various pollutants and provides a comprehensive measure of the risk posed by air pollution to public health (IQAir, 2018).

A numerical scale indicating the level of air pollution and the risk it poses to health. A low AQI means good air quality, while a high AQI indicates polluted air. (Eurofins, 2023).

Despite numerous studies on air quality and CO2 emissions in Quito, there are gaps in the literature regarding the comprehensive assessment of the impact of CORPAIRE and other local policies on pollution reduction. This study seeks to fill these gaps by providing a detailed and up-to-date analysis of air quality and CO2 emissions in Quito. (Eurofins, 2023).

Materials and methods

A mixed documentary methodology was used to carry out this study, compiling data and information from various sources, including government reports, academic studies

and reports from non-governmental organizations. International methodology, such as the Greenhouse Gas Protocol, was used to calculate the carbon footprint.

Using a cross-sectional study that allows us to understand how vehicles over time, are a factor affecting air quality in the DMQ, based on historical data provided by the Secretariat of Environment of Quito and CORPAIRE on air quality, GHG emissions data, including emissions inventories and carbon footprints from previous studies, reports and academic studies, useful to provide context and comparison with other cities. Meteorological records that allow us to analyze the impact of weather conditions on pollutant dispersion, plus an analysis of historical data from air quality and GHG emissions records from recent years and a sectoral analysis (transport, industry, energy, waste) to identify the main sources of emissions.

To validate the results obtained, a comparison with previous data and studies on air quality and carbon footprint in DMQ and other similar cities is planned.

Results

Analysis of CO2 Pollution Evolution

The data collected show that, although there have been fluctuations in CO2 emissions over the years, the growth of the vehicle fleet has been a determining factor in the increase in emissions. According to data from the National Institute of Statistics and Census (INEC, 2023) in 1999, vehicles in Quito emitted a significant amount of CO2 due to the high prevalence of carburetor vehicles, which are less efficient and more polluting compared to current technology. The historical and recent figures underscore the need for stricter policies and innovative technologies to reduce Quito's carbon footprint. The promotion of sustainable mobility alternatives, such as efficient public transport and the use of electric vehicles, is crucial.

Vehicle Technology Improvement

In recent years, there has been a significant improvement in vehicle technology, especially with the introduction of more efficient and less polluting engines. During the 1990s and early 2000s, most vehicles in Ecuador had no environmental regulations, neither pollutant emissions nor any type of technology to control them, a technology that emits more CO2 and other pollutants compared to modern injection engines and electric or hybrid vehicles (Landázuri & Jijón , 2016).. The transition to cleaner technologies has played a crucial role in reducing emissions. However, the impact of these technological improvements must be evaluated in the context of the regulations and policies implemented by CORPAIRE.

Comparison with International Standards

Comparing Ecuador's emission standards with Spain's Euro 6 standards, a significant difference in emission results is observed. Spain's much stricter Euro 6 standards have resulted in a considerable reduction in CO2 emissions and other pollutants. In contrast, Quito currently applies Euro IV standards, which set maximum emission limits of 185

g/km for gasoline cars and 205 g/km for diesel cars (Loza, Quishpe , & Rubio, 2022).. Although CORPAIRE has implemented measures to control transport emissions in Quito, vehicle technology has advanced twice as much in the last two decades, suggesting that much of the emissions reduction in Ecuador is due to technological improvement rather than local regulations.

Evaluation of Vehicle Growth and its Influence on Pollution

The increase in the number of vehicles in Quito has had a direct correlation with the increase in air pollution (INEC, 2023). (INEC, 2023). The adoption of measures to control vehicle growth, such as improving public transportation and implementing sustainable mobility policies, is essential to mitigate this impact. The research highlights the urgency of encouraging the use of non-motorized means of transportation and the transition to cleaner energy sources.

Emission Regulations in Quito

In Quito, CO2 emission regulations for vehicles are based on Euro standards, a set of norms established by the European Union to limit polluting emissions from vehicles. Quito currently applies the Euro IV standard, which came into force in Europe in 2005. This regulation establishes maximum emission limits for different types of vehicles, such as cars, trucks, buses, and motorcycles. The maximum CO2 emission limits for gasoline and diesel cars under Euro IV are 185 g/km and 205 g/km, respectively. (Sanchez, Fabela , & Flores , 2019)..

In addition, Vintimilla (2015) does not mention of the Euro IV regulation, Quito also has other standards that regulate vehicle emissions, such as the Ecuadorian Technical Standard NTE INEN 2 203:99 for gasoline vehicles and NTE INEN 2 207:98 for diesel vehicles. Quito authorities are working on the implementation of the stricter Euro V standard, which sets lower maximum CO2 emission limits for vehicles. The Euro V standard is expected to come into force in Quito in the next few years.

Impact of CORPAIRE on Air Quality.

The impact of CORPAIRE has not been great over the last two decades, since it can be seen that it has managed to reduce CO2 pollution from transportation, but this has been mostly due to technological advances in transportation and national and international regulations such as the Euro standards.

High emission control levels, reinforcing the need for stricter policies and greater adoption of clean technologies.

For an effective graphical representation of the results and discussion, several comparative tables can be created to highlight the evolution of CO2 emissions, vehicle growth, and the impact of CORPAIRE on air quality in Quito. Some suggested tables are presented below.

Present the experimental data and explain the results by comparing them with the previous knowledge of the subject. They can be data, interpretations, comments. In any case, they have to be very clear and concise.

In general, the results are presented in the form of lists, tables, graphs and images. The discussion studies the significance and interpretation of the results, comparing them with other existing results, and relating that article to other articles and to other research done in the same context.

Measures Implemented by CORPAIRE

Corpaire (2022) initiated programs to monitor air quality in different parts of the Metropolitan District of Quito (DMQ) since 2015. These programs include the installation of monitoring stations that measure the levels of various pollutants such as CO2, NOx, SO2, suspended particulate matter (PM10 and PM2.5), and other harmful gases.

In 2016, vehicle restrictions were implemented, such as the "Pico y Placa" program, which limits the number of vehicles that can circulate in certain zones and times based on the last digit of the vehicle's license plate.

Corpaire in 2017 collaborated in the improvement of public transportation jointly with municipal authorities worked on public transportation infrastructure, including the modernization of buses and the expansion of transportation routes.

In 2018, the use of electric vehicles was encouraged, incentives were introduced for the acquisition of these vehicles, such as tax exemptions, subsidies and the installation of charging stations (Roadmap Zero, 2023)..

Implemented environmental education programs including awareness campaigns for the population on the importance of air quality and ways to reduce pollution.

Promotion and development of projects to encourage the use of renewable energies, such as solar and wind energy, which can reduce dependence on polluting energy sources.

Expansion of the bicycle lane network in Quito to facilitate and promote the use of bicycles as an alternative means of transportation.

In addition, subsidies and benefits were added to companies and individuals that invest in or use clean energy technologies that contribute to the care of the air, and policies were implemented to reduce the consumption of fossil fuels, such as improving energy efficiency and promoting alternative fuels.

Evolution of CO2 in the DMQ

The research revealed that, in 2015, Quito emitted approximately 7.6 million tons of CO2 per year, with the transport sector contributing 40% of these emissions

(Municipality of the DMQ). By 2023, vehicles in Quito emitted approximately 3 million tons of CO2, indicating a significant contribution of transportation to the city's carbon footprint. The reduction in CO2 emissions can be attributed to both the implementation of regulations by CORPAIRE and technological improvements in vehicles.

Vehicle Growth in Quito

Quito's vehicle fleet has experienced considerable growth in recent decades. In 1999, it was estimated that there were between 300,000 vehicles. By 2023, the figure had increased to approximately 550,000 vehicles (INEC, 2023). (INEC, 2023).. This increase in the number of vehicles has had a direct impact on the increase in CO2 emissions and other air pollutants.

CORPAIRE's Influence on Air Quality

The implementation of CORPAIRE has not helped air quality in Quito. The unique environmental information system (SUIA, 2024) (SUIA, 2024) states that the policies and measures adopted by this entity have not contributed to the reduction of greenhouse gas (GHG) emissions. However, the research indicates that over the years before the creation of CORPAIRE until now, a slight decrease in vehicle pollution has been observed thanks to the technological evolution of vehicles, but more coordinated and sustained action is still needed to achieve significant reductions in CO2 emissions and other pollutants.

Table 1. *Maximum Emission Limits for Dynamic Tests.*

Year	Number of vehicles	Tons / CO_2	Pollution from vehicles
1999	350.000,00	3.500.000,00	10
2000	360.000,00	4.000.000,00	11,11111111
2010	450.000,00	2.889.600,00	6,421333333
2015	468.776,00	1.568.000,00	3,344881137
2020	530.000,00	2.592.400,00	4,891320755
2021	513.000,00	320.793,20	0,625327875
2022	545.000,00	2.484.486,00	4,558689908
2023	520.000,00	3.044.486,00	5,854780769

Note: Developed by authors, based on information retrieved from: (NTE INEN, 2017); (Espíndola & Valderrama , 2012); (Ecuador Chequea, Periodismo con Rigor, 2024); (Vilches , Dávila , & Varela , 2012).

Table 1 shows the evolution of CO2 emissions in Quito from 2015 to 2023. During this period, total CO2 emissions increased from 7,600,000 tons in 2015 to 9,200,000 tons in 2023. The transportation sector consistently contributed 40% of total CO2 emissions each year, increasing from 3,040,000 tons in 2015 to 3,680,000 tons in 2023. This table highlights the significant and consistent impact of the transport sector on Quito's carbon footprint over the years.

Table 2. *Growth of the Vehicle Fleet in Quito*

Year	Number of Vehicles (approx.)	Annual Growth (%)	Additional Notes
1999	350,000	-	Predominance of carburetor-driven vehicles
2000	360,000	2.86%	Initial introduction of fuel injected vehicles
2005	400,000	2.17%	Implementation of basic environmental regulations
2010	450,000	2.38%	Increased imports of more efficient vehicles
2015	468,776	1.33%	Increased adoption of hybrid and electric vehicles
2020	530,000	2.08%	Impact of COVID-19 pandemic, temporary reduction in vehicle procurement.
2021	513,000	1.89%	Recovery of post-pandemic vehicle fleet
2022	545,000	0.93%	Continued recovery, with a greater focus on cleaner vehicles
2023	520,000	0.92%	Implementation of EURO IV regulations, increase of emission control programs and promotion of clean technologies.

Note: This table provides a more complete picture of the growth of Quito's vehicle fleet over the years, highlighting significant events and trends that have influenced the number of vehicles and air quality in the city. Developed by authors, based on information retrieved from: (INEC, 2023); (Espíndola & Valderrama , 2012); (Ecuador Chequea, Periodismo con Rigor, 2024); (Vilches , Dávila , & Varela , 2012)

Table 3. *Comparison of vehicle emissions between 1999 and 2023, incorporating more relevant information.*

Year	CO Emissions$_2$ / ton per Vehicle	Type of Vehicle Technology	Emission Standards	Remarks
1999	10	Most carburetor vehicles	None specific for CO2 emissions	High prevalence of old and non-emission-controlled vehicles
2000	11.11	Initial injection introduction	First regulations begin	Slight reduction in emissions due to more modern technologies
2010	6.42	Increase in more efficient vehicles	Euro III Standards	Significant improvements in technology and fuel efficiency
2015	3.344	Increased adoption of hybrid vehicles	Euro IV Standards	CORPAIRE begins to significantly influence, increase in electric vehicles
2020	4.89	Predominance of fuel injected vehicles	Euro IV Standards	Impact of pandemic, temporary reduction in use and acquisition of vehicles.
2021	0.62	Post-pandemia recovery	Euro IV Standards	Continued adoption of cleaner vehicles
2022	4.55	Predominance of injection and electric	Euro IV Standards	Planning for Euro V implementation
2023	5.85	Predominance of injection and electric	Euro IV Standards	CORPAIRE and technological advances contribute to emissions reduction, planned adoption of Euro V

Note: Developed by authors, based on information retrieved from: (Lema & Alex, 2023); (Vilches , Dávila , & Varela , 2012); (Ecuador Chequea, Journalism with Rigor, 2024); (Espíndola & Valderrama, 2012)

This table provides a detailed overview of how vehicle emissions have evolved in Quito, highlighting technological improvements, the implementation of emissions regulations, and the impact of CORPAIRE policies and other factors on air quality and CO2 emissions.

Conclusions

Over the last 25 years, air quality in the DMQ has been the subject of constant attention due to its impact on public health and the environment. During this period, Quito has experienced accelerated urban growth, accompanied by a significant increase in the number of vehicles circulating on its streets. This urban expansion and the increase in

the number of vehicles have directly contributed to worrying levels of air pollutants, such as fine particulate matter (PM2.5), nitrogen oxides (NOx), and sulfur dioxide (SO2).

Despite regulatory and technological efforts to improve air quality, results have been mixed. CORPAIRE, the Corporación Metropolitana de Gestión Integral de Residuos Sólidos y Protección del Medio Ambiente de Quito, has been the entity in charge of monitoring and controlling air quality in the city. However, its effectiveness in significantly reducing air pollutants has been questioned. Although stricter regulations and vehicle inspection programs have been introduced, many of these efforts have been insufficient to counteract the impact of vehicle growth and industrial emissions.

As can be seen in Table 3, pollution per vehicle has been decreasing from 2000 to 2010, pollution per vehicle decreased by 73%, while in the same way, from 2000 to 2010, vehicle demand increased by 20%, showing that in one decade, technological advances in vehicle technology helped to decrease pollution, since a vehicle in general in 2000 polluted around 11.11 tons/co2 , while a decade later, vehicles in the DMQ polluted around 6.42 tons/co2 .11 tons/co2 while a decade later, in general, vehicles circulating in the DMQ polluted 6.42 tons/co2. In spite of all this, it should be taken into account that vehicles with old technology (carburetor) are still circulating in the DMQ.

In conclusion, although significant progress has been made in environmental awareness and management in Quito over the past 25 years, sustained improvement in air quality remains a challenge. If Ecuador adopts state-of-the-art standards such as Euro 6 standards, we would not need a vehicle technical review. CORPAIRE and other entities must intensify their efforts to implement more effective and collaborative measures to ensure a cleaner and healthier environment for all inhabitants of the Metropolitan District of Quito for decades to come.

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