2024

Kenya Public Commuter Operations

CO_2 Emissions Assessment: Route Nairobi CBD-JUJA

WHITE PAPER

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WHITE PAPER:

Public Commuter Operations CO2 Emissions: Route CBD-JUJA

This report delves into the assessment and calculation of CO_2 emissions within the Matatu Operations in Kenya for the CBD-JUJA urban corridor, a service provided by multiple commuter bus companies/Sacco's. It meticulously examines the carbon footprint along the specified route for an unnamed Matatu company, analyzing emissions per trip, hour, day, and week to provide a detailed understanding of the operations of bus commuter services on environmental impact.

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EXECUTIVE SUMMARY: DRIVING SUSTAINABLE TRANSPORT PRACTICES IN THE PUBLIC COMMUTER SECTOR

Climate change poses one of the most pressing challenges of our time, urging industries and governments to prioritize sustainability initiatives, especially in the transport sector. This report sheds light on the carbon footprint associated with the public transportation operations along the bustling Nairobi-JUJA transport corridor, in Kenya. This initiative introduces a groundbreaking approach to assess, measure and potentially manage greenhouse gas (GHG) emissions for transport companies, such as public commuter service providers, aligning with global sustainability goals outlined in the 2030 Agenda and the Paris Climate Change Agreement.

At the core of this initiative lies the development of comprehensive GHG emissions calculations tailored specifically for public commuter operations based on activity (distance-based approach) adopting a 'scopes' approach, specifically focusing on Scope 1, which encompasses direct emissions. By quantifying emissions associated with daily matatu operations, we pave the way for strategic interventions aimed at reducing environmental impact while enhancing operational efficiency. This approach not only empowers **environmental conscious** transport and logistics operators to customize corporate strategies but also promises significant financial savings and fosters an engaged workforce and clientele committed to sustainability.

The current report delves into the intricacies of carbon measurement systems for passenger transportation, addressing key issues such as approach selection, boundary definition, emission factor evaluation, and data sourcing. Data was sourced from two fronts, the first is the leg (route) attributes such as the total distance in km and the number and distances between stops. The second been the vehicle operating system (VoR), which entailed the type of vehicle, the average tare/net weights, number of seats, YoM, fuel type etc. The model specification leveraged published data on carbon emission factors for various transport modes, where we laid down the foundation for informed decision-making and sustainable practices adoption.

With this report we aim to enhance environmental conscious transport companies, their sustainability efforts through collaborative seminars, sensitization programs, and greening initiatives with the objective of fostering a culture of collaboration and environmental responsibility across their operations. The overarching goals is to promote sustainability, facilitating informed decision-making, enhancing financial efficiency, and fostering environmental responsibility through policy and green initiatives in the transportation industry.

AeroTrail endeavors to lead the way in driving sustainable transport practices, setting a new standard for environmental stewardship in the public commuter sector.

AEROTRAIL LIMITED

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ABOUT *AEROTRAIL* LIMITED

AEROTRAIL is an aviation, logistics and supply chain consultancy, market research, data analytics and modelling solution provider focused on the African air transport and logistics market. The company was established in early 2021 by a group of enthusiastic aviation and supply chain enthusiast driven by the lack of reliable data on the African aviation and logistics market. Its main objective is to gather, analyze, model, simulate, store, and provide domestic, regional, and continental aviation market data specific to Africa and also provide supply chain solutions for the logistic and public transport industry.

AEROTRAIL aims to promote inclusiveness and enhance the environmental sustainability of transportation, logistics and warehousing operations throughout the East African region and the African continent as a whole. By working closely with relevant authorities and industry players, **AEROTRAIL** intends to contribute to the improvement and development of the sectors ensuring that decision-making is based on reliable data and fostering the growth of a sustainable and efficient air transport and logistics operations network in Africa.

Our Vision

To become the regional partner and leader in aviation & logistics consultancy, progressive market research and predictive data analytics tailor-made for our client's needs.

Our Mission

To provide meaningful solutions and innovative approaches that are dedicated to helping our partner organizations to make essential business decisions through actionable market research and data analytics.

Our Company objectives

1. To position the company as the premium aviation and logistics consultancy in the region by inculcating excellence in service delivery and market solutions.
2. To learn and understand our client's organization's goals and objectives so as to be able to provide the prerequisite market-driven solutions.
3. To apply proven market research techniques and data analytics to provide meaningful and actionable solutions aligned with our client's needs.
4. To build and strengthen the progressive and meaningful partnerships that ensconce the spirit of camaraderie.

Our Core Beliefs and Values

PROMPTness is our language, and so are our services.

1. ***Professionalism***: We only understand one way of doing things, and that is the right way.
2. ***Reliability***: We are dependable and worthy of your trust as consistency is our priority
3. ***Open-Minded***: We are open to new ideas, and open criticism as these usher us to different perspectives, critical thinking and rationality.
4. ***Motivation***: We are eager to deliver on your needs
5. ***Passion***: Motivation leads to passion and we are passionate about what we do.
6. ***Trustworthy***: We are unwavering in providing recourse to your needs, we do not only aim at pleasing but saying it as it is.

1.0 INTRODUCTION

In today's world, addressing the pressing issue of global warming has become an urgent priority, as we grapple with the escalating threats posed by climate change and environmental degradation. Recognizing the critical need for swift action, the international community has rallied behind initiatives such as the Paris Agreement (PA), forged during the Conference of the Parties (COP) 21. Serving as a landmark accord, the PA builds upon the framework established by the United Nations Framework Convention on Climate Change (UNFCCC) and aligns with the Sustainable Development Goals (SDGs), signalling a collective commitment to combatting climate change on a global scale (The National Treasury of Kenya).

Despite these concerted efforts, the challenge remains formidable, particularly in light of the continued rise in global carbon dioxide emissions observed in recent years. These emissions, known to be a primary driver of the greenhouse effect, are closely linked to significant environmental harm and adverse climate impacts. Among the sectors contributing to this concerning trend, transportation of both people and goods emerges as a prominent source of greenhouse gas (GHG) emissions, significantly exacerbating the climate crisis.

In 2020, the transportation sector emerged as a significant contributor to global carbon dioxide (CO_2) emissions, accounting for a staggering 24% of direct emissions resulting from fuel combustion worldwide. Moreover, it constituted a substantial portion of the global oil demand, representing 57%, and consumed approximately 28% of the total energy supply. In stark contrast, rail transportation made a relatively minor impact, contributing just about 0.3% to direct CO_2 emissions during the same period.

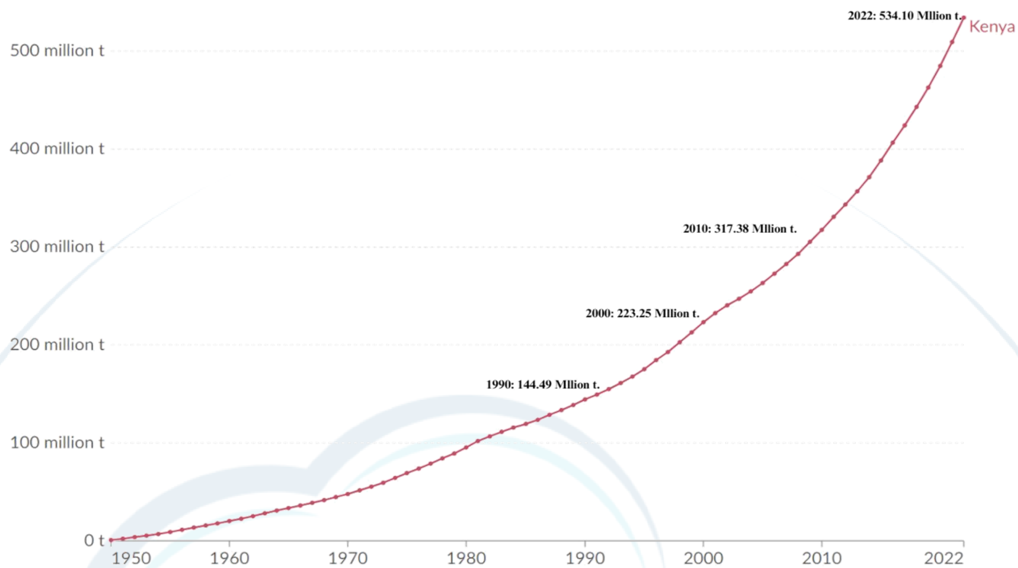
According to the (International Energy Agency) IEA, despite trucks and buses comprising less than 8% of vehicles (excluding two- and three-wheelers), they were responsible for over 35% of direct CO_2 emissions from road transport in 2022, totalling 2,282 $MtCO_2$. Alarmingly, emissions in this sector have shown an upward trend, rebounding to nearly their 2019 levels in 2023. These statistics underscore the urgent need for strategic interventions and sustainable practices within the transportation sector to effectively mitigate its significant environmental impact.

1.1 Kenya Sustainability Initiatives.

Kenya, as the host of the United Nations Environmental Program (UNEP), has demonstrated its commitment to environmental stewardship through various initiatives. By ratifying the Paris Agreement and submitting its National Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC), Kenya reaffirmed its dedication to combating climate change.

In December 2016, Kenya submitted its NDC, outlining ambitious goals for both adaptation and mitigation efforts. The adaptation contribution focuses on integrating adaptation measures into Medium-Term Plans and implementing actions to enhance resilience to climate change impacts. Meanwhile, the mitigation contribution aims to reduce greenhouse gas (GHG) emissions by 30% by 2030 compared to the 1990 baseline scenario of 143 million tonnes of carbon dioxide equivalent ($MtCO_2e$), as outlined by the (Ministry of Environment and Foresty). According to statistics from Our World In Data, Kenya's cumulative CO_2 emissions stood at 543.10 million tonnes of carbon dioxide equivalent ($MtCO_2e$) as of 2022 (See Figure 1) this represents about 0.07% of share of global CO_2 emissions. These figures underscore the significance of Kenya's efforts to mitigate climate change and transition towards a sustainable future.

Figure 1: Kenya yearly Cumulative CO_2 emissions



Data Source: GlobaL Carbon Budget (2023)

Climate change action in Kenya is guided by the Climate Change Act (Number 11 of 2016), which serves as a comprehensive framework for integrating climate change considerations across various sectors. Central to this legislative framework is the National Climate Change Action Plan (NCCAP), established to oversee the implementation of climate change initiatives in Kenya, including those outlined in the Nationally Determined Contributions (NDC). A key component of Kenya's climate change strategy is the National Green Fiscal Incentives Policy Framework. This policy framework is designed to steer the country's economy towards a sustainable, low-carbon, and climate-resilient development trajectory. It achieves this by leveraging fiscal and economic mechanisms to incentivize green investments and practices, thereby facilitating the transition to a more sustainable future.

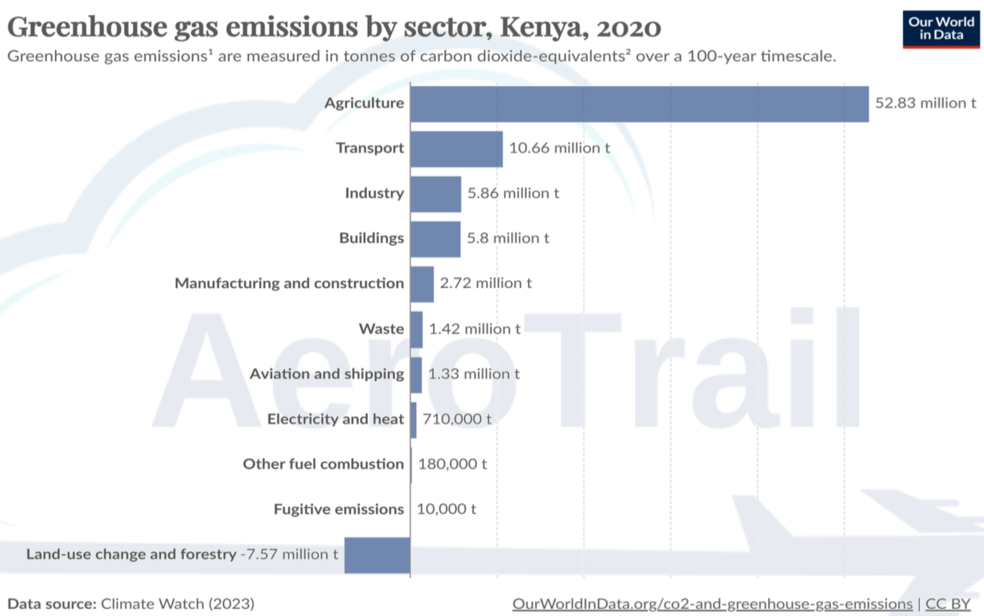
To foster greater engagement in environmental sustainability efforts and mitigate greenhouse gas emissions within the private sector, the Kenyan government has taken proactive steps through tax policy reforms, as outlined in the Kenya Finance Act Number 22 of 2022 (Finance Act). This legislation introduces a corporate tax incentive tailored for companies engaged in carbon market exchanges or emission trading systems. Under this new provision, reflected in the Finance Act's amendment of the Third Schedule of the Income Tax Act Cap 470 of the Laws of Kenya, companies operating certified carbon market exchanges or emission trading systems will benefit from a reduced tax rate. Specifically, these entities will enjoy a 15% tax rate for the initial ten years from the commencement of their operations, following certification by the Nairobi International Financial Centre Authority. Subsequently, the tax rate will revert to the standard 30% thereafter.

1.2 Kenya Transportation Sector

The transport sector in Kenya encompasses various modes including road, rail, air, water (maritime and inland water), pipeline, and non-motorized transport. As is the case in most countries, transportation plays a critical role in facilitating economic activities and is a significant consumer of petroleum products, accounting for over two-thirds of the total consumption in Kenya. Public transportation in Kenya primarily relies on land-based modes, notably buses and matatus (minibuses), with the railway system playing a complementary role. Matatus, especially prevalent in the capital city of Nairobi, are favoured for their flexibility and affordability, filling a vital gap in the transportation network alongside private cars and taxis.

According to the Transport Sector Climate Change Annual Report 2018-2019, in 2015, Kenya's domestic transport sector emitted a total of 11.25 $MtCO_2e$. The sector has set a target of reducing emissions to 3.46 $MtCO_2e$ by 2030, based on a baseline of 21 $MtCO_2e$. This implies that by 2030, annual emissions should not exceed 17.54 $MtCO_2e$. Estimates for 2020, as reported by Climate Watch, indicate that the transport industry was the second-largest emitter of Greenhouse (GHG) Gases in Kenya, accounting for 10.66 $MtCO_2e$, following the agricultural sector. However, this figure is lower than the emissions reported in 2015, primarily due to reduced travel resulting from the COVID-19 pandemic.

Figure 2: Emissions per sector



1.3 Objective of the Study

AeroTrail, with this study wants to portray the importance of undertaking sustainable transport operations. By conducting a one-week pilot study from February 7th to February 13th, 2024, to assess the carbon emissions of a unnamed bus company operating the route between the Nairobi CBD station and JUJA, Kiambu County. The objectives of the study were as follows:

Objective one: To comprehensively evaluate the environmental impact of 33-seater bus operations along the Nairobi CBD to JUJA route, with a specific focus on determining and assessing average trip carbon footprints.

Objective two: To advocate for industry-leading environmental sustainability practices within the public transport sector. By identifying opportunities to reduce emissions, the aim is to pave the way for potential utilization of carbon offsetting and credit financial instruments in the future by transport companies.

2.0 CO_2 EMISSIONS CALCULATION FRAMEWORK

2.1 CO_2 Emissions Calculations Approaches

Drawing upon established standards such as the GHG Protocol and EN16258, which provide comprehensive frameworks for measuring and managing greenhouse gas (GHG) emissions, this study adopts the 'scopes' approach. Specifically focusing on Scope 1, which encompasses direct emissions from sources owned or controlled by the company, including vehicle emissions from public transportation activities. This study segmented the transport services into individual legs (for the report Nairobi CBD to JUJA) for analysis. GHG emissions are then calculated with an activity-based focus using the Tank-to-Wheel (TTW) emission factors.

Based on the above steps, the GHG protocol has defined three calculation approaches:

a) ***Consumption based-approaches*** – This approach is particularly useful for assessing the true environmental impact of consumption patterns, global supply chains, and international trade. It highlights the indirect emissions associated with imported goods, shedding light on the environmental consequences of demand for products from regions with different emission profiles. The Consumption-based method uses the following formula:

CO_2 emissions = fuel consumption x fuel emission conversion factor

[kg CO_2 -emissions = liters x kg CO_2 per liter fuel]

b) ***Distance-based approaches (or activity)*** – This method focuses on quantifying emissions based on the distance travelled by vehicles or goods in transportation activities. This approach takes into account factors such as the mode of transportation, the type of vehicle, and the distance covered, all of which influence the amount of emissions produced during the journey. The activity-based method uses the following formula:

CO_2 emissions = Transport distance by transport mode x CO_2-emission factor per km by transport mode

[kg CO_2 emissions = km x kg CO_2 per km]

c) ***Key-figure-based approach*** **–** This approach involves using specific performance indicators or key figures that are relevant to the organization's operations to quantify its emissions. Instead of relying solely on general metrics, this approach tailors the emission calculations to the organization's specific activities, processes, or products. Key figures could include various operational parameters such as production outputs or energy consumptions.

For the study we utilised the distance-based (or activity) approach, as this was the most convenient calculation approach considering the single sector (leg) pilot study and data availability.

2.2 Effect of congestions on emissions calculation

Urban passenger transport operations are subject to external mobility conditions such as congestion. In this sense, operation times, and consequently total emissions, are affected. To measure the effect of congestion, emissions-speed curves have been developed. For this pilot study, the guidelines of the Commission of the European

Communities in the MEET study are taken as reference (Transport Research Laboratory, 1999). This study carried out in 1999 reports the emissions-speed functions for different types of vehicles and fuels.

In the case of buses for transporting passengers, the function of the emissions factor is of the form:

Equation 1: Emissions factor function

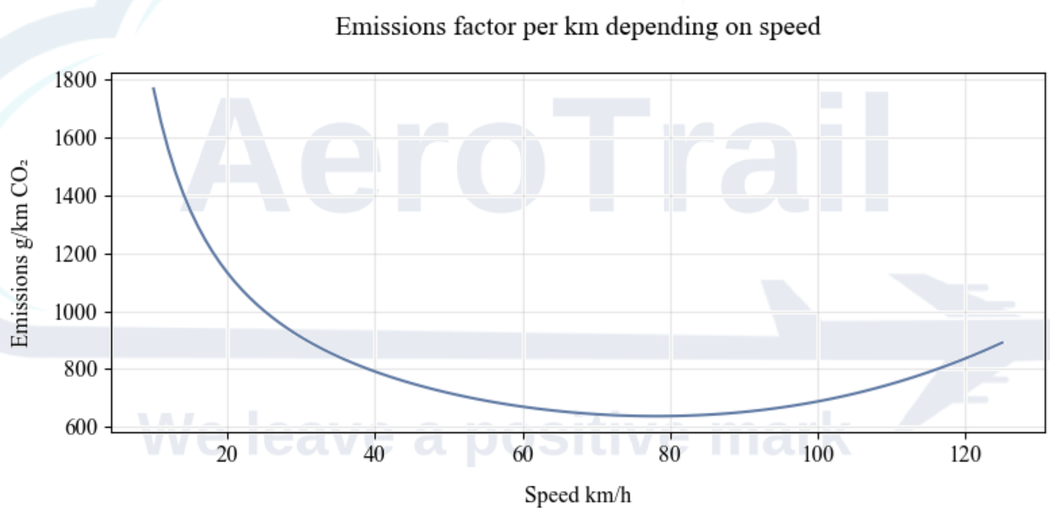
$$\varepsilon = K + av + bv^2 + cv^3 + \frac{d}{v} + \frac{e}{v^2} + \frac{f}{v^3}$$

Where:

K is a constant,
a - f are coefficients and,
v is the mean speed of the vehicle in km/h.

The coefficient values for the buses are 523, 0, -0.0487, 0.000527, 12501, 0, 0 respectively. With these values, the emissions velocity curve results in Figure 3.

Figure 3: Emission factors based on bus speeds.



In general, it's important to note that lower speeds, typically ranging between 10 to 20 km/h, tend to result in higher emissions. This phenomenon occurs due to the vehicle's operational characteristics, where frequent stops and starts lead to increased fuel consumption and consequently higher emission levels. Additionally, at lower speeds, the vehicle's engine may operate less efficiently, further exacerbating emissions.

Conversely, speeds within the range of 60 km/h to 100 km/h are associated with lower emissions. This is primarily attributed to the distribution of emission particulates across a wider range at higher speeds, leading to a more efficient combustion process. As a result, emissions are comparatively reduced when vehicles operate within this speed range. These findings underscore the importance of considering vehicle speed as a crucial factor in emission management strategies, with implications for urban planning, traffic management, and the adoption of cleaner transportation technologies.

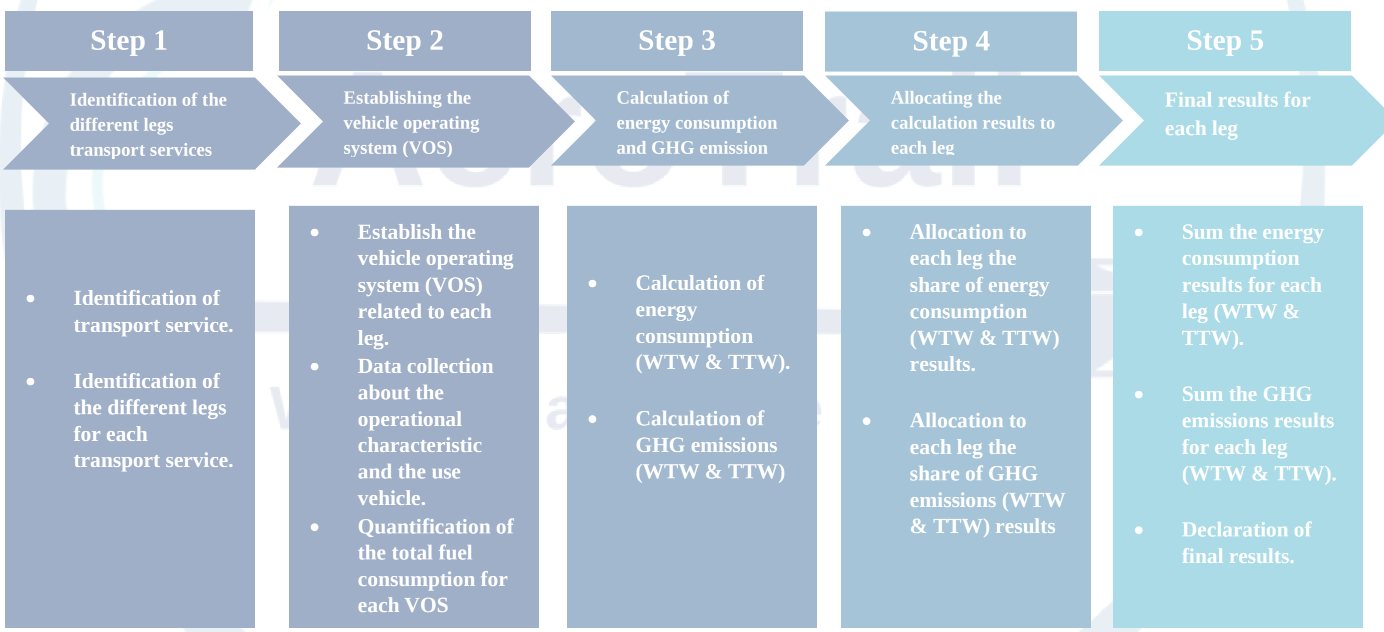
2.3 Public Commuter Operations CO_2 Emission Model Specification & Methodology

In accordance with the guidelines outlined in the EN16258 Standard and the GHG Protocol, a five-step process to calculate the greenhouse gas (GHG) emissions of the commuter buses for the Nairobi CBD-JUJA leg (segment). Here, a "leg" refers to the distance travelled by a bus from the pick-up point A (CBD station) to the drop point B (JUJA station) and vice versa. In Figure 4, we outline the five steps and provide a brief description of the general implementation methodology utilized.

STEP 1: The first step entailed the identification of the leg of passenger transport service, for this study, CBD station to JUJA. In this step, it is necessary to categorize the transport services which were used during the transportation and then to identify the different bus stop or reference points along the transport corridor. Apart from the loaded trips, all the empty trips related to the transport operations were also considered.

STEP 2: The second step focused on the establishment of the Vehicle Operation System (VOS) for the transport sector. In this step it was necessary to collect a series of operational data (e.g., fuel consumption, distance, load factor, vehicle capacity, empty distances) and vehicles characteristics (e.g., registration number and types of vehicles, period of activity of vehicles), to quantify the total fuel consumption per VOS.

Figure 4: Implementation steps for the calculations of transport energy consumption and GHG emissions.



STEP 3: The calculations of the bus fleet GHG emissions commenced through the conduction of a series of specific equations and models. The specifications of the models are according to EN16258 standard for both energy consumption and GHG emission calculations. For each VOS which participates in the transport operation, the following indicators were calculated:

i. Tank-to-wheel (TTW) energy consumption (MJ)
ii. Tank-to-wheel (TTW) GHG emissions ($KgCO_2$)

STEP 4: In this step we assigned four results from the third step to the different bus operating in the study sector. Focusing on this allocation unit, the transport activity will be quantified by multiplying the load/quantity of passengers (in Tonnes) by the distances travelled (in Kilometres).

STEP 5: Lastly, the values of total energy consumption and GHG emissions for the complete transport service should be estimated by summing the corresponding values for all buses that operated in the leg within the study period. The declaration of the results is completed under the tank-to-wheel (TTW) emissions.

3.0 DATA COLLECTION

Data collection for this study involved a combination of qualitative and quantitative methods. Conducted as a cross-sectional study over one week from February 7th to February 13th, 2024, the study focused on assessing the company bus fleet operations along the route between Nairobi CBD and JUJA. Data collection occurred daily from 0600hrs to 2200hrs to capture a comprehensive picture of the fleet's activities throughout the day.

The data collection process involved gathering information from various sources to comprehensively assess the carbon footprint of the transport route. This included route characteristics such as the distance in kilometres between the start and end points, as well as the distance and time it takes between different bus stations, considering variations during peak and off-peak periods. Additionally, data was collected from vehicle operating systems (VoS), including details about the type of bus operating, real-time vehicle seat occupancy, movement patterns, departure and arrival times, passenger weights, and other relevant factors (Figure 5).

Figure 5: Passenger data collection.

The route covers approximately 31.5 kilometres and encompasses 20 stops from CBD to JUJA. These stops include CBD, Khoja, Ngara, Pangani, Muthaiga, National Youth Service (NYS), KCA University, Allsoaps, Garden City, Roysambu, Kahawa Sukari, Kenyatta University, Clayworks, Bypass, Ruiru, Kimbo, Toll, Kenyatta Road, and JUJA. Under normal conditions, the journey takes around 41 minutes, with intermittent stops at least four bus stations. For a direct route, it takes approximately 35 minutes. However, during rush hour periods, the travel time can extend to up to 70 minutes due to increased congestion.

Table 1: Data classification

Route Attributes			Vehicle Operating System		
Distance of route/leg		31.5 km	**Vehicle type**	Isuzu NQR	
Avg. time it takes to complete the route	Normal Hours	42 mins	**Fuel Type**	Diesel	
			Tare weight	Av. 4500 kgs	
			Payload of Bus	34-seater	Appro. 2000kgs
	Peak hours	Up to 70 mins	**Euro Standard**	(II, III & IV)	
			Fuel consumption	A litre Between 6-7 km	

Typically, the vehicles used to cover this route utilize Isuzu chassis, specifically the NQR type, with an average tare weight of 4,500 kilograms and seating capacity for 34 passengers, including the driver. Throughout the week-long observation period, a total of 364 buses, each with unique registration numbers, were observed operating at varying frequencies. The fleet comprised vehicles assembled between 2012 and 2023, adhering to Euro standards II to IV. Notably, all buses were equipped with diesel engines.

4.0 RESULTS

4.1 Total Emissions CBD-JUJA

Throughout the one-week study period, the total CO_2 emissions assessed between the Nairobi CBD station and JUJA Station amounted to 77.5 tons of CO_2 for in regards to the unnamed bus company operations which translate to 4030 tons of CO_2 emissions per annum. The average daily emissions was around 11 tons of CO_2. Considering that the average number of daily trips by the matatu company on this route was 431, the average emissions of a trip assessed was 25.6 kg of CO_2. When divided among passengers, including the driver, this translates to approximately 731.42 grams of CO_2 per individual per trip. For comparison, consider that a mature tree typically absorbs approximately 25 kilograms of CO_2 per year, based on **EcoTree**[1] calculations.

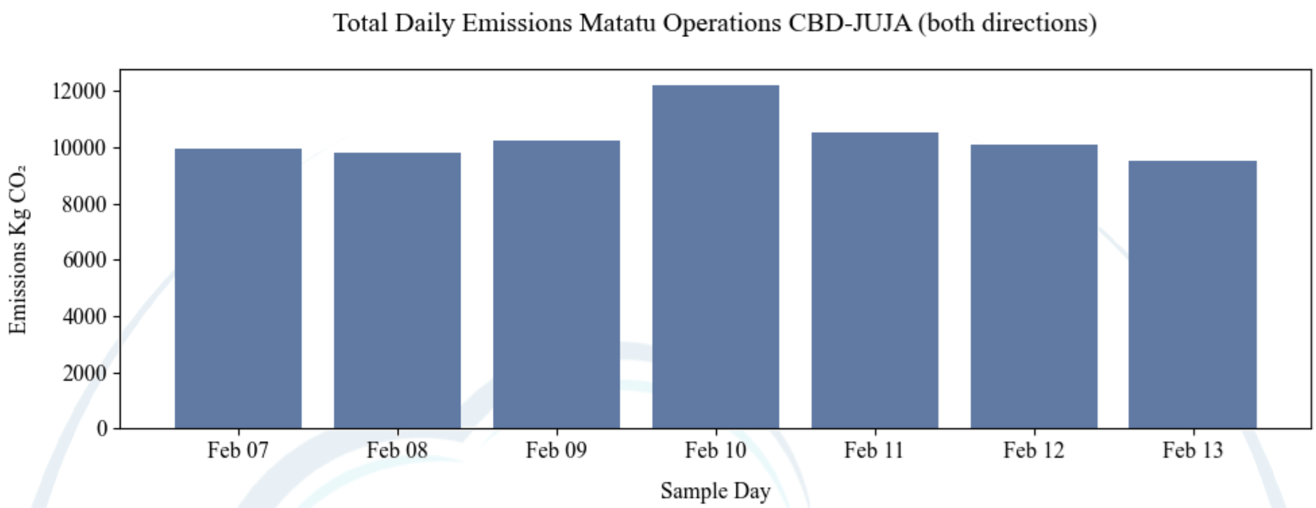
In essence, to neutralize the emissions produced by each journey along the CBD-JUJA route, planting at least one tree per trip would be imperative, amounting to a total of 431 trees to offset daily operations emissions. Extrapolating this requirement for an entire year, the bus company would need to plant 161,200 trees to compensate for the emissions generated by their matatu operations along the Nairobi CBD-JUJA route.

4.1.1 Emissions per day

As mentioned previously, the average daily emissions generated on the Nairobi CBD-JUJA route amount 11 tons of CO_2 for the unnamed bus company. When we extrapolate this result to the different days of the week, it reveals some interesting insights. Surprisingly, Saturday emerges as the day with the highest emissions, totalling about 12.800 kg of CO_2, followed by Sunday, with Friday closely behind. This result suggests that Saturdays witness the highest Matatu movement in the week, while mid-week, particularly Tuesday the 13th, recorded the least, as depicted in Figure 6.

[1] How much CO2 does a tree absorb? https://ecotree.green/en/how-much-co2-does-a-tree-absorb

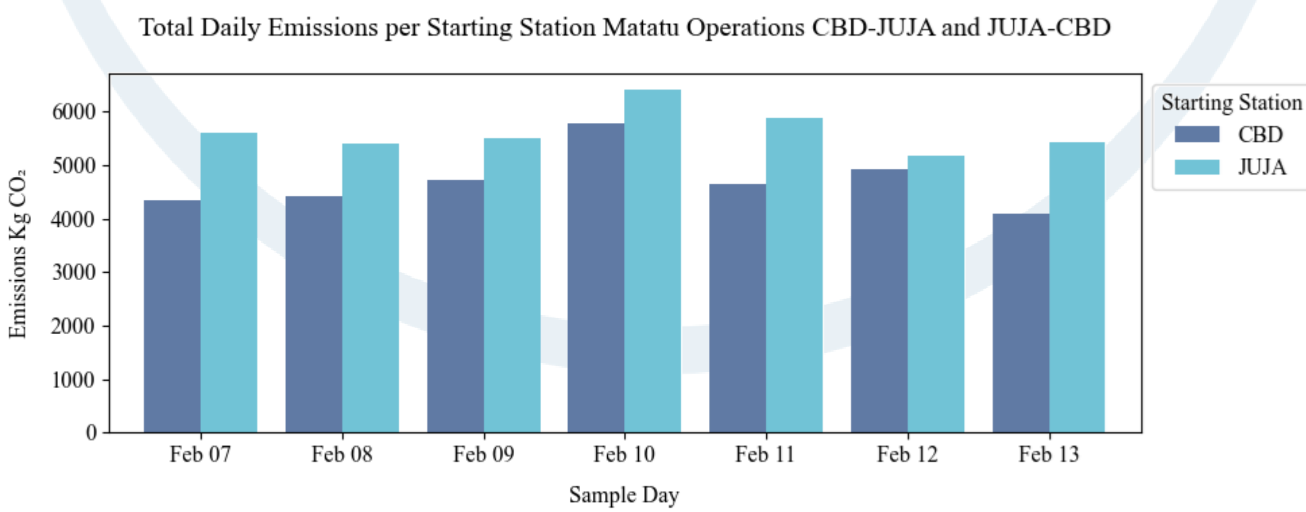
Figure 6: Daily emissions along the study route



4.1.2 Emissions per Starting Station

Upon reviewing the data based on the direction of movement, specifically from Nairobi CBD to JUJA and vice versa, an interesting trend emerges. The analysis indicates that there is a higher carbon dioxide emission into the environment from trips originating from JUJA compared to those originating from the CBD throughout the week except for Monday, February 12 (see Figure 7). This discrepancy can be attributed to the longer duration of trips in the direction from JUJA to the city centre, leading to increased emissions. Furthermore, as highlighted in the previous subsection regarding daily emissions, Saturdays consistently exhibit the highest emissions in the week from both directions of travel. This finding underscores the significant impact of weekend travel patterns on carbon emissions in the public commuter transport sector.

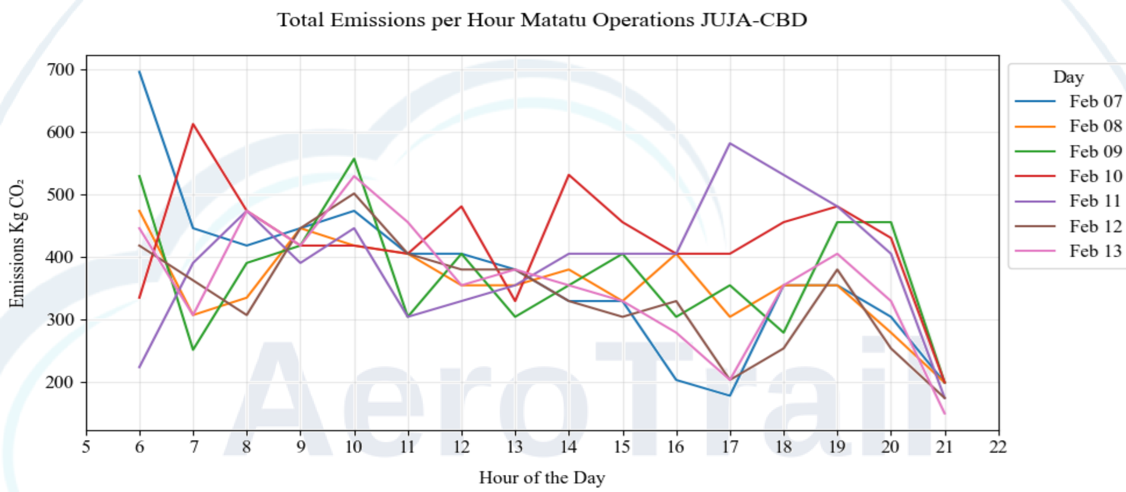
Figure 7: Emission per Start Station (point)



4.1.3 Emissions per hour

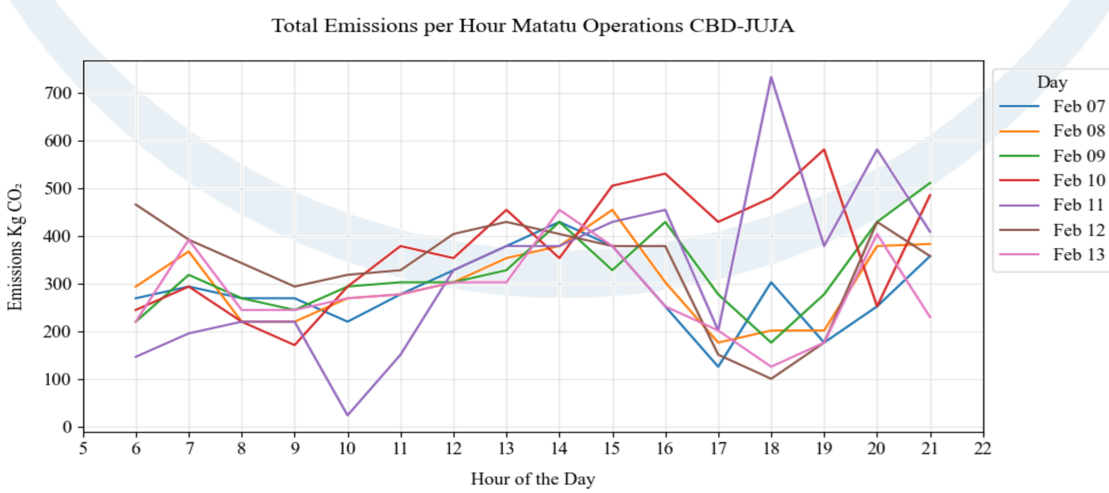
The discrepancy in emissions between trips originating from JUJA and those from Nairobi, CBD can be attributed to the distinct traffic patterns experienced along the route. Specifically, during the morning rush hour, which typically occurs between 0630hrs and 0930hrs, heavy traffic congestion is observed when entering the city center from JUJA (see Figure 8). This congestion starts from Allsoaps and extends all the way to the Pangani interchange, with additional delays encountered from Ngara to the CBD station. As a result, the usual travel time of 42 minutes extends to over an hour, leading to increased emissions during this period. Conversely, the traffic congestion during the evening rush hour is not as severe as in the morning.

Figure 8: Distribution of Emission per hour JUJA-CBD



Typically, buses encounter jams between Ngara and the Pangani interchange, as well as between Allsoaps and Roaster near Garden City. However, unlike the morning rush hour, these traffic jams tend to be more fluid and moving. Despite this, the overall travel time remains longer for trips from JUJA to the CBD compared to the reverse direction. Figure 9 illustrates the notable influence of traffic congestion on both travel times and emissions along the CBD-JUJA route throughout the day.

Figure 9: Distribution of Emission per hour CBD-JUJA



During the outbound journey from the CBD, traffic congestion remains minimal to non-existent from the early morning hours until late afternoon, peaking around 1500hrs. However, congestion significantly intensifies starting from 1600hrs, marking the onset of the evening rush hour, and persists until approximately 2100hrs. Notably, on February 11, 2024, at 1800hrs, congestion reached its peak with emission of more than 700kgs of CO_2, likely exacerbated by an accident leading to a severe traffic jam out of the city centre. Understanding these congestion patterns enables the bus company to devise strategic measures aimed at optimizing routes, mitigating emissions, and enhancing overall operational efficiency.

4.2 Emissions per route segments

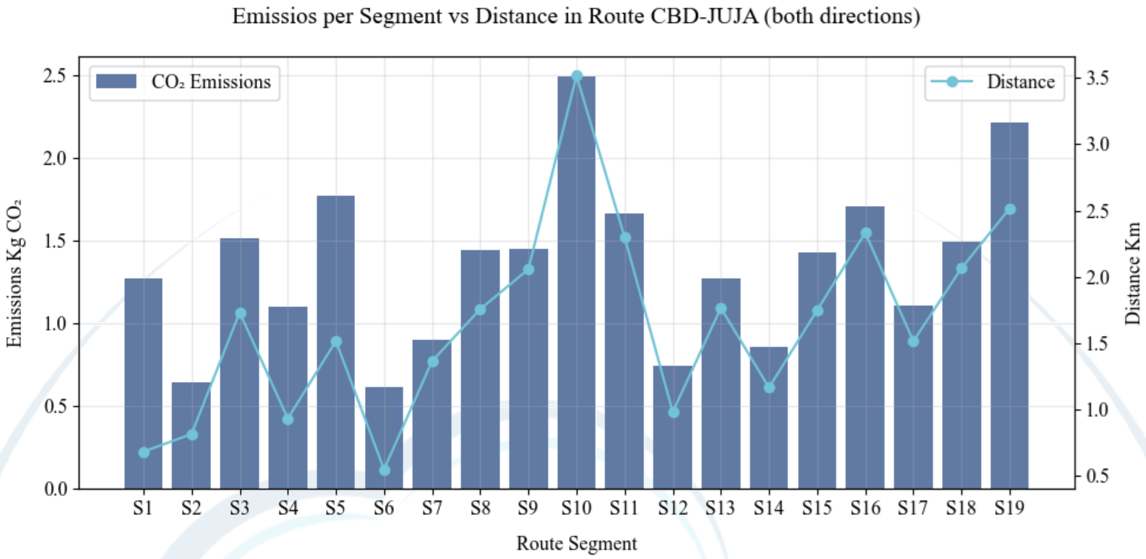
As explained earlier, the route between CBD and JUJA was segmented into different sectors, known as reference stops. There are a total of 19 segments from start to end as outlined in Table 2 below. In the table we give the distance and the average time in minutes it takes (duration) between the reference points/stations. During the calculation of emissions, the travel times in each segment vary depending on the time of day.

Table 2: Route segmentation

Segment	Route	Time [Mins]	Distance [Km]	Speed [Km/h]
S1	CBD-Khoja	0:04	0.68	9.84
S2	Khoja-Ngara	0:01	0.82	36.75
S3	Ngara-Pangani	0:03	1.73	32.84
S4	Pangani-Muthaiga	0:02	0.93	21.00
S5	Muthaiga-NYS	0:04	1.52	22.75
S6	NYS-KCA	0:01	0.55	28.29
S7	KCA-Allsoaps	0:01	1.37	61.50
S8	Allsoaps-Garden City	0:03	1.76	35.17
S9	Garden City-Roysambu	0:02	2.06	61.75
S10	Roysambu-Githurai	0:04	3.52	52.75
S11	Githurai-Kahawa	0:02	2.30	51.75
S12	Kahawa-KU	0:01	0.98	44.25
S13	KU-Claywork	0:02	1.77	48.92
S14	Claywork-Bypass	0:01	1.17	46.67
S15	Bypass-Ruiru	0:02	1.75	39.37
S16	Ruiru-Kimbo	0:03	2.33	46.67
S17	Kimbo-Toll	0:02	1.52	45.50
S18	Toll-K-road	0:02	2.07	53.14
S19	K-road-Juja	0:05	2.52	29.23

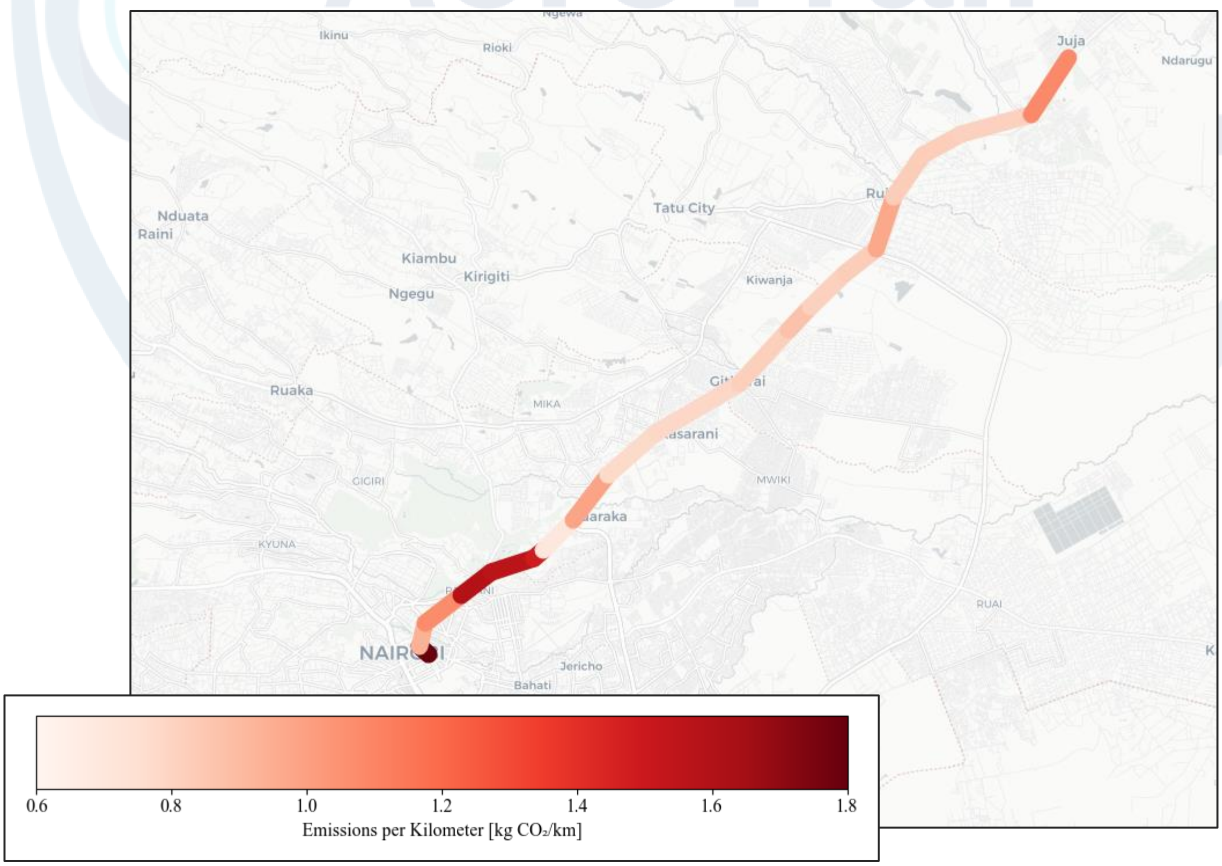
When evaluating each segment, an interesting analysis is the amount of emissions per kilometre. Thus, it is possible to show which sectors are most exposed. It is worth noting that it is in the centre of the city, between CBD and Khoja, where the highest amount of emissions per kilometre are generated, around 1.85 $kgCO_2/km$ (See Figure 10). While the Roysambu to Githurai route (S10) exhibits higher CO_2 emission coefficients, approximately 2.5 kg of CO2, it's essential to note that the distance between these two stations is relatively longer, averaging 3.52 kilometers. Consequently, the emissions generated along this route are dispersed over a wider geographical area compared to routes S1 to S4.

Figure 10: Difference in emissions and distance per route segment (gap)



To provide a clearer understanding of the emission dynamics along the CBD-JUJA route and vice versa, we have created a geographical map (refer to Map 1 below) showcasing emission levels between the stations at both ends of the study route.

Map 1: Emission factors between stations



Upon analysis of the map, it becomes evident that the stretch between CBD and Khoja experiences the highest emissions, primarily attributed to severe traffic congestion during morning hours. This is closely followed by the sectors between KCA University and the Pangani Interchange, particularly during the morning rush hour. Additionally, congestion is observed between Ngara and Pangani interchange, Allsoaps and Garden City in the evening, stemming from the exit towards EABL, as well as at Juja station. Conversely, the segments between Khoja and Ngara, and Ruiru and Kenyatta Road, offer smoother rides, resulting in relatively lower emissions.

5.0 REPORT RECOMMENDATIONS

Our comprehensive assessment of the Nairobi CBD-JUJA leg of public commuter operations has shed light on the environmental impact and opened doors for proactive steps towards sustainability.

Recommendations have been intentional omitted.

To learn more about mitigation recommendations, please contact AeroTrail, info@aero-trail.com

6.0 ABOUT THE AUTHORS

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Alex Kipkorir Koech is a Co-founder of AeroTrail and also serves as a consultant. He holds a Bachelor's degree in Aviation Management and a Master's in Business Administration (MBA) with a focus on Strategic Management from Moi University. Additionally, he has earned an advanced Master of Science degree in Maritime and Air Transport Management from the University of Antwerp. Alex's research interests revolve around transportation strategies such as market research, business planning, marketing strategies, and other related areas.

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Rafael Arevalo-Ascanio is currently working towards a Ph.D. in Applied Economics at the University of Antwerp while also serving as a Co-founder at AeroTrail. He holds a background as an industrial engineer from the National University of Colombia and has obtained a master's degree in industrial engineering with a specialization in logistics from the same institution. Additionally, Rafael has completed an advanced master's degree in Maritime and Air Transport Management from the University of Antwerp. His research focuses on transport, logistics, and supply chain modeling as primary areas of interest.

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