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Assessing Carbon Emissions from Public Transport in Kandahar City: Trends, Impacts, and Sustainable Solutions

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Abstract

This investigation studied the fuel consumption and CO_2 emissions from public transport in Kandahar City, Afghanistan, focusing on the years 2022 and 2023. Public transport, comprising motorbikes, three-wheelers, private vehicles, taxis, and buses, is a major source of urban mobility but also adds heavily to the city's carbon emissions. Using a top-down methodology, based on fuel consumption data from 81 petrol stations, this study calculated the CO_2 emissions emitted by these automobiles. Results revealed that fuel used, particularly petrol, was more from 2022 to 2023, leading to a proportional increase in CO_2 emissions. In 2023 petrol fuel consumption was 38.5 million liters, and diesel fuel consumption was 7 million liters. As a result, that year's total CO_2 emission from public transport based on petrol and diesel fuel consumption was 107990 tons. Public transport drove 72% of CO_2 emissions in 2022, while in 2023 it drove emissions slightly lower at 71%, whereas private cars represented 63% of CO_2 emissions, and buses had the least emissions in Kandahar. The analysis supports the need for government policies to implement the support for fuel-efficient transport modes to lessen public transport impacts on the environment in Kandahar City.

Keywords: Carbon Emissions, Public Transport, Fuel Consumption, Sustainable Transport, CO_2 Emissions, Urban Mobility, Environmental Impact, Air Pollution

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1. Introduction

Only Earth is the single planet in the solar system known to contain life, as it is the only planet with a climate that is suitable for humans to live in, it has a sufficient amount of oxygen and a temperate climate [1]. Unfortunately, human behavior has severely disturbed this delicate balance, particularly with the increase of greenhouse gas (GHG) emissions[2]. Recently, there has been an obvious increase in greenhouse gas (GHG) emissions, specially carbon dioxide (CO_2), methane (CH_4), and chlorofluorocarbons (CFCs), associated with rapid industrialization and urbanization[3], [4]. Contemporaneously, these GHG emissions have contributed to more extreme weather events, sea level rise, disrupted ecosystems, and global warming temperatures, all associated with anthropogenic climate change[5].

One of the major contributors to carbon gas emissions is the global transportation system. This factor is particularly significant in developing communities and urban centers, where it plays a key role in the release of carbon emissions. Fossil fuels, which serve as the primary energy source for transportation systems, significantly contribute to carbon dioxide emissions. This issue is especially evident in developing countries, where transportation infrastructures are still evolving [6], [7]. Urban centers around the world, due to their higher population densities compared to other regions, tend to have greater energy consumption, which ultimately results in increased use of resources and higher levels of carbon dioxide emissions [8].

Major cities in Afghanistan, including Kandahar—which is both developing and located in an arid environment are experiencing similar environmental challenges [9]. Kandahar has recently become one of the most populous cities in Afghanistan and is undergoing rapid urban growth [4]. As a result, the city's transportation system has significantly transformed, with a wide variety of vehicles operating daily. These include taxis, motorcycles, rickshaws, and buses, which serve to meet the mobility needs of the urban population [10]. However, the increasing number of vehicles in Kandahar's transportation system has also led to serious environmental problems and is considered one of the key contributors to air pollution [11].

Environmental pollutants in Kandahar City are linked to several factors, one of which is carbon dioxide emissions a subject that has not been adequately studied [12]. Investigating the transportation system of Kandahar is considered an important topic, as it can provide a clearer understanding of the level of pollutants generated by this sector [13]. Therefore, it is essential to examine the issue of urban transportation-related emissions in Kandahar in order to better assess their environmental impact [14].

The primary objective of this study is to examine and assess the carbon dioxide emissions produced by the public transportation system in Kandahar City. This research evaluates the fuel consumption of various types of transportation vehicles and, accordingly, measures the resulting carbon dioxide emissions. The aim is to determine the extent of pollutants released into the environment by this sector. It is important to highlight that this study also seeks to identify the challenges associated with this issue and draw attention to the broader implications, particularly those related to climate change [15], [16].

One of the additional objectives of this study is to pave the way for a national and international environmental discourse concerning the transportation system. This discourse could have a direct impact on improving the transportation system in Kandahar to an acceptable standard. Moreover, the study aims to provide practical recommendations for relevant authorities and stakeholders involved in the provision of urban transportation services [17], [18].

1. 1 Carbon Emissions

Carbon emissions, also known as greenhouse gas (GHG) emissions, are a significant contributor to global warming. These gases include Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulfur Hexafluoride (SF_6), and Nitrogen Trifluoride (NF3) [19], [20]. CO_2 is the largest contributor, accounting for a significant portion of total GHG emissions. The 2010-2019 period saw an increase in GHG emissions, with 79% originating from energy, industry, transport, and building sectors [21]. This rise is largely attributed to human activities driving climate change, ocean acidification, and environmental degradation [22]. The 2019 report reported atmospheric CO_2 concentrations at 410 PPM, CH_4 at 1866 PPB, and N_2O at 332 PPB [23].

1. 2 Greenhouse Gas (GHG) Emissions from Transport

Transportation, including road, rail, aircraft, and shipping, is a significant contributor to (GHG) emissions. Road transportation accounts for 70% of emissions, followed by aviation (12%), shipping (11%), and rail (1%). The sector contributes about one-quarter of global GHG emissions, making it the second-largest emitter after energy production [24]. In 2019, global GHG emissions from the transport industry reached 8.7 gigatons of CO_2-equivalent [25]. Asia ranked highest due to rapid urbanization and increased mobility needs. By 2022, emissions dropped slightly to 7.97 gigatons of CO_2-equivalent, but road transport remains a significant contributor [26].

1. 3 Carbon Dioxide (CO_2) Emissions from Transport

The transportation sector is the largest contributor to global GHG, with CO_2 being the most significant greenhouse gas. Burning fossil fuels for vehicle propulsion emits huge volumes of CO_2, accounting for 56% of the greenhouse effect [27]. Transportation emissions come from passenger vehicles, commercial trucks, and buses, accounting for 28.9% of worldwide CO_2 emissions in 2017 [28]. Other sectors including aviation, shipping, and rail also contribute to CO_2 emissions, albeit at lower amounts. The transport sector's share of global CO_2 emissions is likely to expand without considerable policy intervention [29].

1. 4 Research Methods for Estimating Transportation Carbon Emissions

Researchers employ two major methodologies to estimate carbon emissions from transportation, A: bottom-up and B: top-down. Bottom-up entails collecting thorough data on vehicle usage and attributes, including elements like mileage, energy consumption, and fuel type. This approach delivers high-resolution estimates at a local or

sectoral level [30]. Top-down, on the other hand, employs broader data like national energy consumption statistics to estimate emissions on a large regional and temporal scale. It calculates emissions based on the overall fuel consumption of different transport modes and the carbon intensity of energy sources used [31], [32].
In China, private vehicles contribute significantly to CO_2 emissions, despite efforts to boost public transportation. Improving energy efficiency, reducing vehicle ownership, and upgrading public transport networks are crucial to reducing transport-related carbon emissions [33]. European studies have found spatial autocorrelation patterns in transport emissions across countries, stressing the significance of coordinated regional measures to decrease carbon footprints [34]. Policymakers are asked to promote modal transitions from vehicle to rail and to strengthen the infrastructure that supports low-carbon travel [35].

1. 5 Policy Implications and Future Directions

Mitigating transportation-related carbon emissions is an important component of global efforts to mitigate climate change [36]. Research suggests that increasing low-carbon public transit, encouraging the use of electric vehicles, and optimizing urban planning can dramatically cut emissions [37]. In developing regions like Afghanistan, upgrading public transport infrastructure and adopting sustainable urban mobility strategies are key steps toward decreasing the carbon footprint of cities like Kandahar [38]. To combat the predicted increase in transportation emissions, governments must embrace integrated methods that consider energy efficiency, technological innovation, and behavior change [39].

2. Methodology

2. 1 Study Area

The research is carried out in Kandahar, A key province of Afghanistan, located in the southern region of the country. Kandahar City, the provincial capital and the second-largest city in Afghanistan constitutes the principal research area. The city comprises 15 districts, each influencing the urban landscape and transportation conditions. This research concentrates on fuel usage data from public transport vehicles in Kandahar City. Kandahar City is situated at 31°37' north latitude and 65°42' east longitude which is shown in Figure 1, a pertinent consideration for environmental and traffic-related effects.

2. 1 Research Method

This research focuses on determining CO_2 emissions from public transit in Kandahar City using a top-down method based on fuel consumption data. The research is conducted by various organizations, including the Engineering Faculty of Kandahar University, the Union of Fuel Stations in Kandahar City, and the Chancellor of Monopolies of Kandahar City. The top-down technique is suitable for calculating carbon emissions from public transport vehicles like buses, taxis, private automobiles, motorbikes, and three-wheelers. The research uses a quantitative approach, emphasizing objective observation and measurement to find universal laws. Data collection involves both primary and secondary sources, with secondary data from fuel usage records maintained by the Chancellor of

Monopolies of Kandahar City and primary data from questionnaires. The methodological framework is shown in Figure 2. The results are analyzed using descriptive techniques, presenting results through tables, charts, and diagrams.

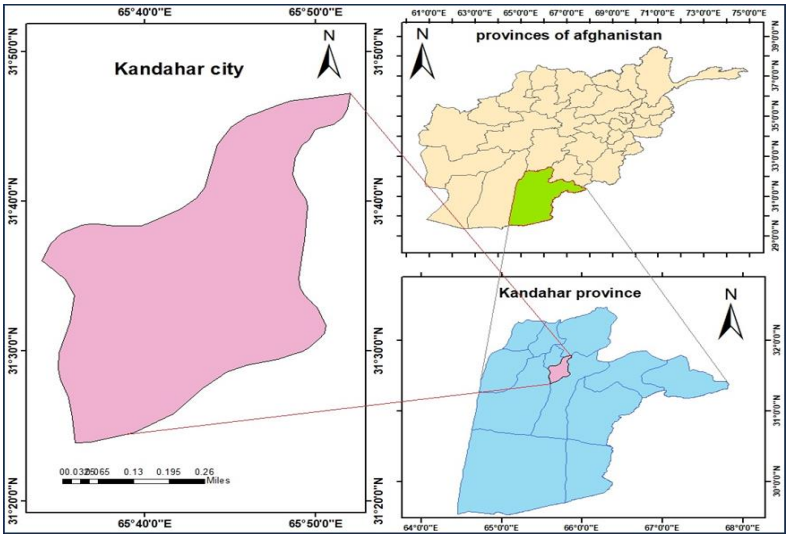


Fig. 1. Study Area (Kandahar City)

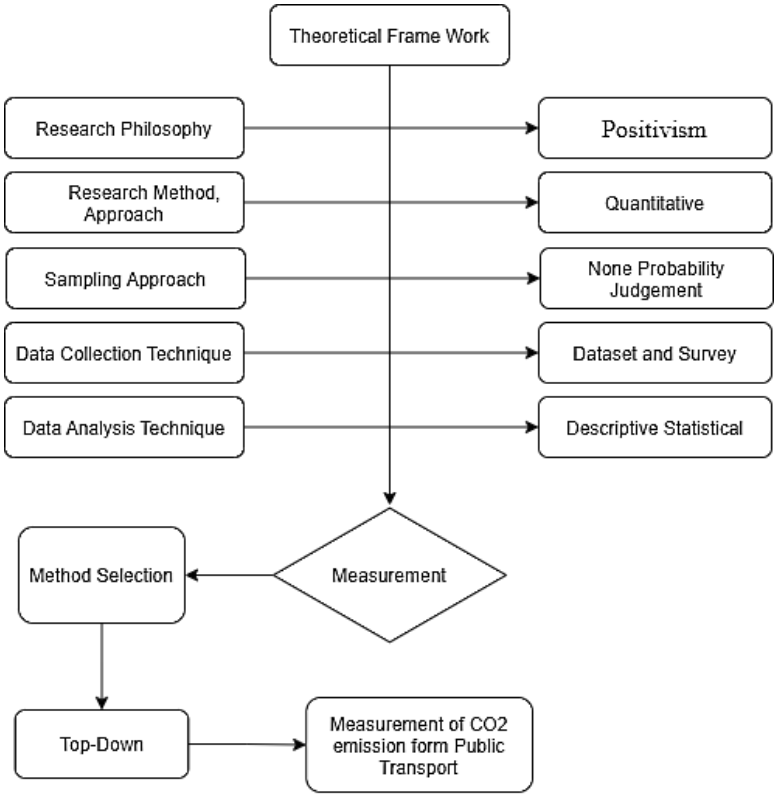


Fig. 2. Methodological Frame Work

The research aims to calculate CO_2 emissions from five types of public transport vehicles in Kandahar City: buses, taxis, private cars, motorbikes, and three-wheelers. Fuel consumption data for petrol and diesel is collected from 81 fuel stations in the city, covering fuel sales for 2022 and 2023. Primary data collection involves conducting surveys at these stations to obtain specific fuel consumption data for each vehicle category. The average annual fuel consumption for each vehicle category is estimated based on survey results. The total CO_2 emissions for each vehicle type in 2022 and 2023 were calculated using Equation (1), based on the greenhouse gas emission factors recommended by the Intergovernmental Panel on Climate Change (IPCC) [23].

$$E_{CO_2} = AD \times EF_{CO_2} \quad (2.1)$$

$E_{CO_2} = Emission \text{ of } CO_2$
$AD = Activity\ Data\ (Fuel\ Consumption\ Data)$
$EF_{CO_2} = Emission\ Factor$

Emission factors for fuels such as petrol are 2.3 kg per Liter and for Diesel is 2.7 kg per Liter [23].
The data is then analyzed to determine the total CO_2 emissions from public transport vehicles in 2022 and 2023, highlighting which vehicle types and fuel sources are the largest contributors to CO_2 emissions in Kandahar City.

3. Result & Discussion

The results revealed that public transport in Kandahar City consumes a significant amount of fuel, with petrol consumption significantly higher than diesel consumption. Between 2022 and 2023, fuel consumption increased significantly, nearly doubling petrol consumption. This rise in fuel usage correlates with an increase in CO_2 emissions, making public transport a major contributor to Kandahar City's carbon footprint. Public transport consumed 18.25 million liters of petrol and 3.2 million liters of diesel in 2022, increasing to 38.59 million liters and 7.12 million liters in 2023 respectively as shown in Table 1.

Table 1. Total Fuel Consumers of Kandahar City

Total Fuel Consumers (Millions Liter)				
Year	**2022**		**2023**	
	Petrol	Diesel	Petrol	Diesel
Public Transport	18.25336	3.198031	38.58979	7.12362
Other Sectors	0.919729	6.513057	1.944417	14.50784
Total	19.17309	9.7110882	40.534209	21.631463

CO_2 emissions in Kandahar City rose significantly between 2022 and 2023 due to increased fuel consumption. Table 2 shows the CO_2 emission results in Kandahar City

and results indicate that public transport, particularly petrol-powered private cars, contributed to the increase, with CO_2 emissions more than doubled to 107,990 tons. Other sectors also experienced increased emissions, although they remain lower than public transport's impact.

Table 2. Total Carbon Dioxide Emitters of Kandahar City

Carbon Dioxide Emission from All Consumers				
Year	**2022**		**2023**	
Consumer	Kg/year	Ton/year	Kg/year	Ton/year
Public Transport	50617408.1	50617.4	107990293.6	107990.3
Other Sectors	19700629.7	19700.6	43643337.2	43643.3
Total	70318037.8	70318.0	151633630.8	151633.6

The results showed that in Kandahar City, private cars are the primary fuel consumers, using 11.71 million liters of petrol in 2022 and 24.76 million liters in 2023. Motorcycles and three-wheelers are the second and third-highest fuel users, respectively. Diesel consumption also increased for buses and taxis. Table 3 shows the fuel consumption of public transportation.

Table 3. Fuel Consumption of Public Transport Vehicles in Kandahar City

Fuel Consumption Data of Public Transport Vehicles (Millions of Liters)				
Year	**2022**		**2023**	
Vehicles	**Petrol**	**Diesel**	**Petrol**	**Diesel**
Motorcycles	4.595244	0	9.7148978	0
3 wheelers	1.7472449	0	3.6938855	0
Private Cars	11.710241	1.8923782	24.756856	4.2152752
Taxies	0.2006281	0.6314752	0.4241519	1.4066119
Buses	0	0.674178	0	1.5017325
Total	18.25336	3.1980314	38.5897916	7.1236196

This research attempted to determine CO_2 emissions from fuel use by public transport and other industries in Kandahar City between the years 2022 and 2023. The research focused on the introduction of formal fuel registration systems in Afghanistan, commencing in 2022. The Financial Presidency of Kandahar City began carefully tracking the amounts of petrol and diesel consumed, providing trustworthy data for these two years.

In 2022, public transport consumed substantially more petrol than other sectors, with approximately 18 million liters used, compared to just 1 million liters by other sectors. Conversely, in that year other sectors consumed more diesel than public transport, utilizing 6.5 million liters compared to public transport’s 3 million liters, as shown in Figure 3. This trend continued in 2023 when public transport petrol consumption climbed

to 38.5 million liters, 20 times greater than other sectors. Diesel usage in that year also climbed for both public transport and other sectors, with public transport using over 7 million liters and other sectors consuming about 14 million liters.
In 2022, overall fuel usage was around 29 million liters, which grew to over 62 million liters in 2023. The ratio of petrol to diesel use remained largely consistent, with petrol usage around five to six times higher than diesel consumption in both years.

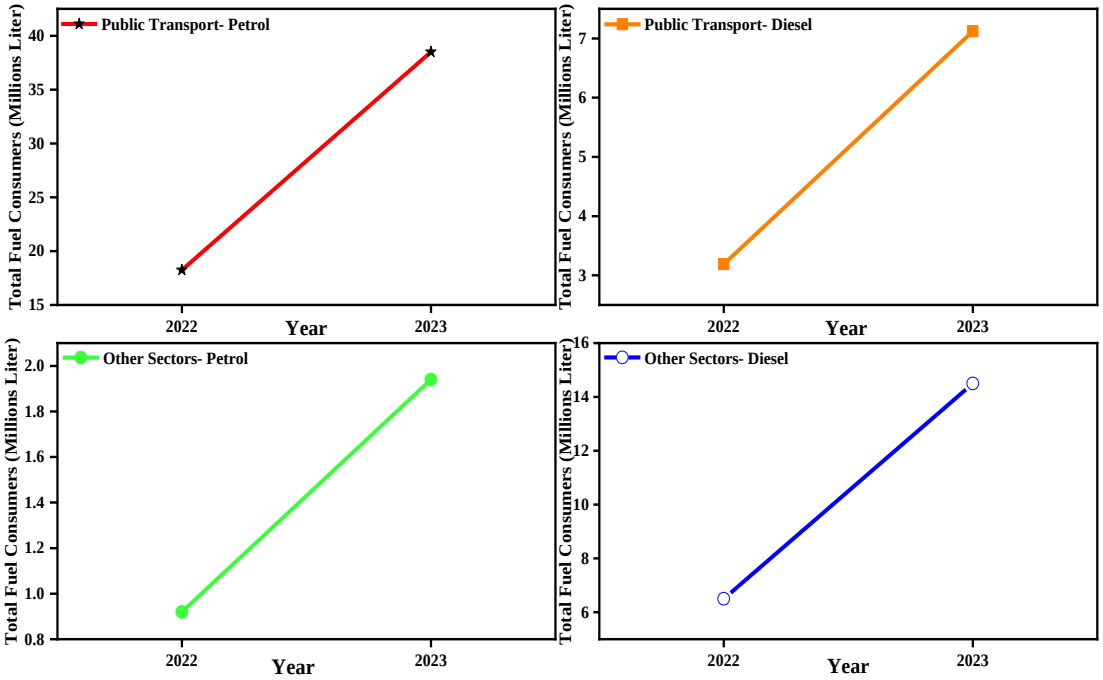


Fig. 3. Total Fuel Consumers of Kandahar City Year-2022,2023

The principal types of public transit in Kandahar City include motorbikes, three-wheelers, private automobiles, taxis, and buses. These cars are commonly utilized in Afghanistan, particularly in urban centers. The research revealed that in both 2022 and 2023, private vehicles were the greatest consumers of fuel, followed by motorcycles and three-wheelers. Figure 4 graph demonstrates the increasing reliance on certain vehicle types for mobility within the city.

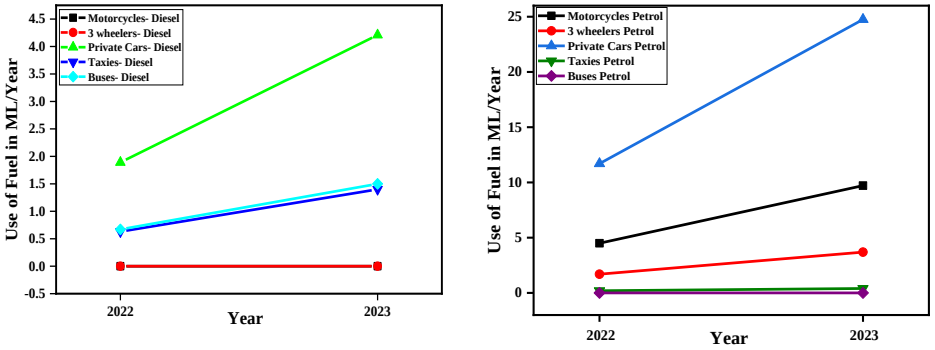


Fig. 4. Fuel Consumers of Public Transport of Year-2022, 2023

The increase in gasoline use also contributed to a dramatic spike in CO_2 emissions [40], [41]. This research also emphasizes the spike in CO_2 emissions, as shown in (Figures 5 - 6) for the 2022 and 2023 years. In 2022, public transport generated over 50,000 tons of CO2 emissions, while other sectors accounted for 19,000 tons, bringing the total to more than 70,000 tons. Public transport was responsible for 72% of total emissions, indicating its considerable environmental impact. By 2023, overall CO_2 emissions had more than doubled, reaching 151,633 tons, with 71% of these emissions related to public transport.

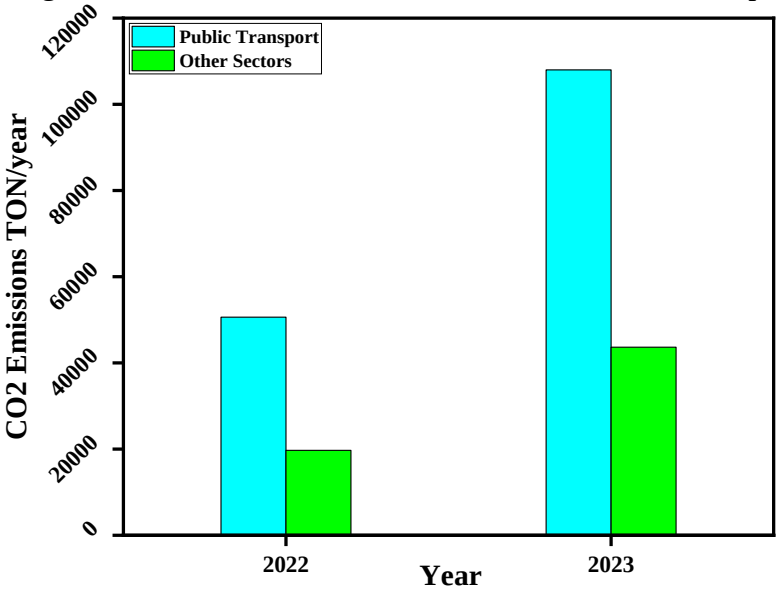


Fig. 5. Total Carbon Dioxide Emission of Kandahar City of Year-2022,2023

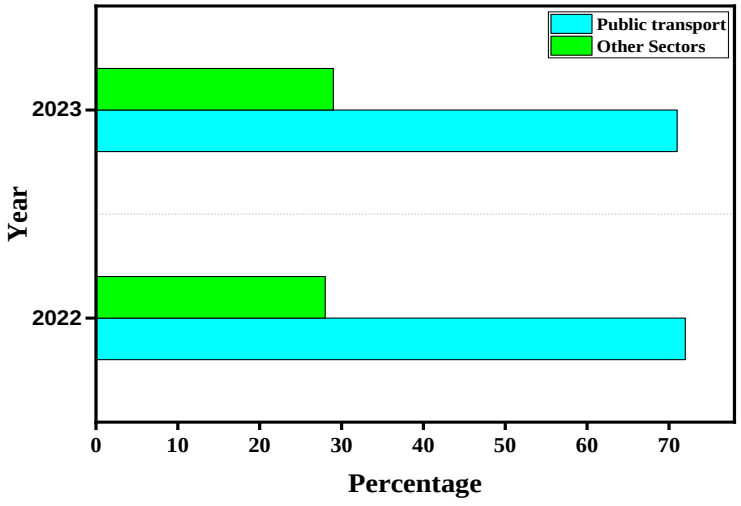


Fig. 6. Carbon Dioxide Emission of Kandahar City of Year-2022, 2023

The Result emphasizes the urgent need to reduce the environmental impact of public transport in Kandahar City. Strategies to minimize fuel consumption and emissions should focus on promoting more fuel-efficient forms of transport, such as buses, and

encouraging the development of cleaner energy options like electric automobiles. Policies targeted at lowering the reliance on private vehicles and motorcycles could help alleviate congestion and reduce emissions, contributing to improved air quality and a healthier urban environment (Figure 7).

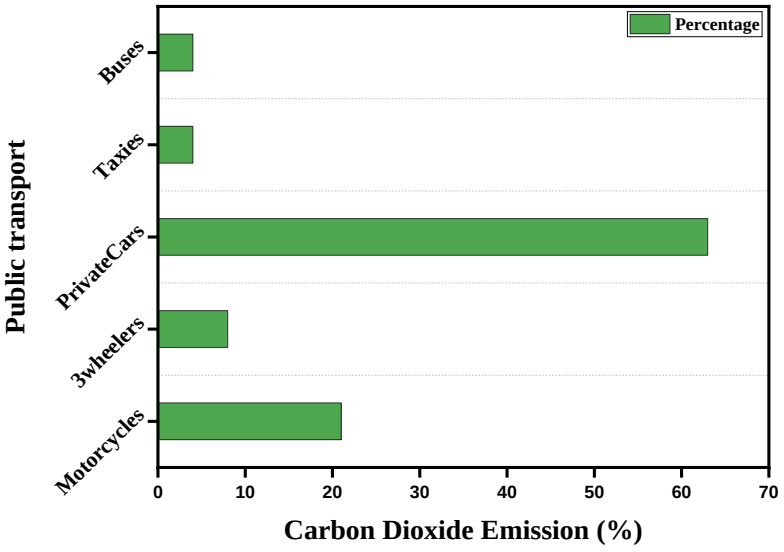


Fig. 7. Carbon Dioxide Emission by Percentage of Year-2022, 2023

4. Conclusion and Further Scope

The research indicated a notable rise in fuel consumption and CO_2 emissions from public transportation in Kandahar City from 2022 to 2023. Public transportation, especially private automobiles and motorbikes, significantly contributes to the city's carbon footprint, accounting for approximately 70% of total emissions. The results highlight the pressing necessity for sustainable transportation solutions to alleviate environmental consequences, particularly in light of ongoing population growth. Advocating for more fuel-efficient vehicles, including buses, and promoting cleaner energy choices such as electric cars is crucial for emission reduction. This research establishes a basis for policymakers to formulate policies to enhance air quality and mitigate the environmental impact of public transportation in metropolitan locales such as Kandahar City.

Future research may broaden the parameters of this study by integrating data from supplementary years to elucidate long-term trends in fuel usage and emissions. There exists the opportunity to examine the effects of integrating electric or hybrid vehicles into the city's public transportation system and evaluate their efficacy in diminishing CO_2 emissions. Furthermore, examining the extensive economic and social ramifications of transport emissions, including health consequences from air pollution, could yield a more thorough comprehension of the effects of public transport on Kandahar's urban landscape. Ultimately, extending the research to additional Afghan cities may provide comparative insights and guide national transportation strategies focused on sustainability.

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Authors Profile



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