



Assessing the Carbon Dioxide from Transportation and Health Outcomes Within Duhok City

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Abstract: This study examines the correlation between the expansion of urban areas, the release of transportation-related pollutants, and the effects on public health in Duhok City. It particularly concentrates on the influence of CO₂ emissions resulting from an increase in transportation activities. The study area, Duhok City, situated at the intersection of Iraq, Turkey, and Syria, is currently undergoing swift urbanization and a consequent increase in the utilization of private vehicles as a result of poor public transit networks. This phenomenon has led to substantial carbon dioxide emissions, which in turn contribute to air pollution and have negative health impacts on the population. The methodology includes a combination of quantitative and qualitative data collection methods, such as measuring air quality, counting traffic volume, and conducting an interview with health specialist and questionnaires to assess health impacts. The research conducts a thorough analysis of current literature and collects empirical data to investigate the connection between emissions from transportation and public health. Its objective is to discover patterns of exposure and the resulting health effects. And The results suggest that the increase in vehicle emissions is a significant factor in the worsening air quality in Duhok, which worsens health problems such as respiratory and cardiovascular diseases. The study enhances our comprehension of the environmental and health obstacles encountered by fast urbanizing cities in conflict-prone areas. It proposes ways for alleviation, with a particular emphasis on improving public transportation systems and lowering reliance on private vehicles as a means to control CO₂ emissions.

Keywords: CO₂ Emissions, Air Pollution, Urban growth, Traffic congestion, Transportation, Health Consequences, transportation- related emissions.

1. Introduction

The United Nations estimated that over 48% of the global population lived in urban areas in 2004, and it is projected to increase to 61% by 2030, posing new challenges for urban planners due to rapid urban growth. Transportation and urban growth are intricately linked subjects. Transportation infrastructure has a dual role in urban development While Duhok is a diverse city in Iraqi Kurdistan, located at the confluence of Iraq, Turkey, and Syria, with a significant Kurdish population and a notable presence of minority communities, and it has recently become a destination for Syrian refugees and internally displaced persons, with a rectangular shape due to its topographical depression and urban expansion extending to the foothills of surrounding mountains, and ample water resources provided by the Duhok dam. Furthermore, the city of Duhok in Kurdistan has experienced rapid urbanization, with 73.2% of the population living in urban areas, leading to a need for more land and an increase in privately owned vehicles, causing problems such as pollution, traffic, poverty, and informal housing. Also, the population of Duhok City has experienced significant growth, more than doubling between 1996 and 2009, and continuing to increase in 2023, leading to urbanization and a reliance on private vehicles due to a lack of public transit infrastructure. Carbon dioxide (CO₂) is emitted during the combustion of fossil fuels and waste materials, contributing to climate change and global warming. And the primary factor in reducing carbon emissions in urban areas is transportation, specifically the use of light-duty vehicles such as cars and motorcycles. Also, Air pollution, primarily caused by the use of fossil fuels in transportation, is a major contributor to death rates and various health issues globally, including chronic obstructive pulmonary disease (COPD), lung cancer, strokes, heart disease, and respiratory ailments, with projections indicating a significant increase in fatalities due to pollution-related factors in the coming years.

The escalating emissions of greenhouse gases (GHGs) in recent decades have generated mounting apprehension over global warming. The emissions originate from several sectors, including electricity, transportation, agriculture, construction, waste management, and afforestation and reforestation. The International Energy Agency reports that the transport sector is the second greatest contributor to greenhouse gas emissions. Constructing transportation infrastructure, such as highways and motorways, is essential for every expanding economy. Rapid infrastructure development to facilitate the rise of new transportation alternatives has led to traffic congestion on the nation's highways. Excessive traffic has several adverse consequences, including heightened levels of noise and gaseous pollution. Individuals who have significant exposure to elevated amounts of carbon dioxide (CO₂) face a significantly

increased likelihood of acquiring many diseases and conditions, such as cancer, cardiovascular disease, respiratory disorders, and premature births. (Abdullah H. Al-Nefaie and Theyazn H. H. Aldhyani).

Lung Cancer in Duhok Governorate

Cancer is a significant cause of death worldwide, accounting for 9.6 million fatalities in 2018. Developing nations that lack sufficient healthcare resources and are exposed to risk factors such as political and economic instability, together with the adoption of Western lifestyles, are expected to experience particularly adverse consequences. (Fitzmaurice et al., 2019).

Despite the establishment of national cancer registries and control programs in Iraq since 1974, there has been a worrisome increase in the incidence of cancer and death rates (Board, 2018). And In 2018, the International Agency for Research on Cancer (IARC) reported that Iraq had more than 25,000 new instances of cancer and over 14,000 fatalities caused by cancer. The predominant forms of cancer in Iraq include breast cancer (BC), lung cancer (LC), leukemia, bladder cancer, and colorectal cancer (CRC). (Bray et al., 2018).

This graph displays a data of the yearly cancer occurrence rates in Erbil and Duhok, categorized by gender, spanning from 2013 to 2019. Both Erbil and Duhok have seen a significant rise in the overall number of cancer cases over the years. and measure the fold increase from 2013 to 2019. Duhok has had a 2.44-fold rise in female cases, a 2.2-fold increase in male cases, and a 2.36-fold increase overall. furthermore, in Duhok total number of cancer cases in 7-year periods was 3,798 cases among females and 3,532 cases among males.

	Erbil			Duhok		
	Female	Male	Total	Female	Male	Total
2013	675 (80)	574 (66)	1250 (73)	252 (38)	234 (35)	486 (36)
2014	995 (114)	761 (86)	1756 (100)	547 (79)	558 (81)	1105 (80)
2015	962 (108)	776 (85)	1738 (96)	529 (75)	520 (73)	1049 (74)
2016	936 (102)	773 (83)	1709 (92)	555 (76)	527 (72)	1082 (74)
2017	1481 (158)	1305 (136)	2786 (147)	576 (76)	520 (69)	1096 (72)
2018	1623 (169)	1420 (145)	3043 (157)	592 (76)	555 (71)	1147 (74)
2019	1884 (192)	1573 (157)	3457 (174)	747 (93)	618 (77)	1365 (85)
Total	8492	7247	15739	3798	3532	7330
Increasing ratio (2013 to 2019)	2.4fold	2.37 fold	2.38 fold	2.44fold	2.2fold	2.36 fold
Female to Male ratio		1.17			1.07	

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2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	Type
175724	163559	155006	144436	135147	119673	110212	104510	103685	101619	95997	86516	74666	Private
17946	17945	17943	17694	17650	17502	17371	17277	17123	16782	13908	11111	9165	Rental
70951	69596	68528	67369	66147	65132	64301	62380	60773	57687	53603	47578	40311	Trucks
4895	4522	4061	3896	3469	2945	2758	2587	2452	2303	2002	1387	960	Agriculture
44	44	44	43	43	43	43	43	43	43	38	19	14	Motorcycle
273021	259042	248836	236633	225571	210186	199513	191574	188775	182965	169725	150194	128205	Total

The provided table displays the statistics regarding the quantity of vehicles that have been officially registered in the Duhok province. The data is categorized and covers a span of years, starting from 2011 and ending in 2023. The vertical axis on the right side displays the different categories of cars, while the years are shown horizontally across the top. The numbers displayed in the table indicate the annual registration count of automobiles in each category. Below is an analysis of the different categories and the patterns observed in the data:

Private car: From 2011 to 2023, the number of cars has shown substantial annual growth, starting at 74,666 and reaching 175,724. This category exhibits the biggest number of registrations and a steady pattern of expansion, suggesting a rise

in the ownership of private vehicles.

Rental cars have experienced gradual and consistent growth, rising from 9,165 in 2011 to 17,946 in 2023. The rise exhibits a reasonably consistent linear pattern in comparison to other categories, indicating a stable and continuous demand for rental cars.

Trucks: The number of truck registrations has increased from 40,311 in 2011 to 70,951 in 2023. This category has had an almost twofold increase over the course of 12 years, potentially indicating a growth in demand for heavy trucks in the logistics, construction, or commercial sectors.

Agriculture: The number of registered agricultural vehicles has experienced a substantial increase from 960 in 2011 to 4,895 in 2023. The province has experienced a fivefold growth, which suggests a significant rise in the use of machinery in agriculture.

Motorcycle: The number of motorcycle registrations has consistently increased from 14 in 2011 to 44 in 2023, however they still remain the least common type of vehicle registered. The growth of this category is moderate, indicating a solid yet limited market for motorcycles.

The total number of registered vehicles has increased by over 100% from 128,205 in 2011 to 273,021 in 2023. The overall trend in all categories demonstrates a positive trajectory, suggesting a rise in car ownership and maybe reflecting economic expansion in Duhok province.

2. Material and Methods

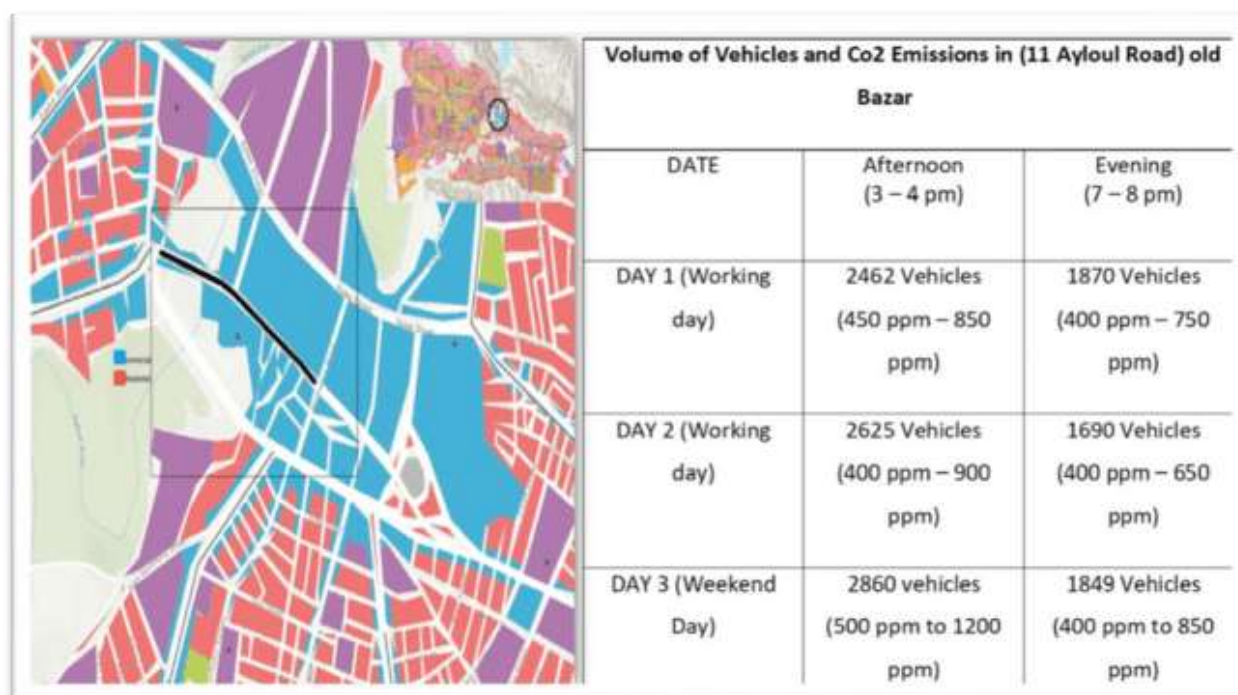
This study, conducted by a master's student in the Spatial Planning Department at Duhok University, was methodically carried out inside the city. The method of sampling used for this research is Stratified sampling: Stratified sampling designs consist of dividing a population into distinct groups (strata) depending on a certain attribute that is known for every individual in the population. Samples are then chosen independently from each stratum. The city can be divided into distinct CO₂ emission exposure categories according to factors including traffic density, proximity to major highways, and urban vs suburban locations. This guarantees that the sample reflects different exposure levels throughout the city. This study examines the impact of transportation-related CO₂ emissions on the health of citizens in Duhok city. Specify certain health outcomes of interest, such as respiratory ailments, cardiovascular disorders, or total rates of illness. and Mixed-used such as observations, Survey, questionnaires, and interviews to provide a complete data-gathering approach that addressed the many components of the research objectives. Seven diverse settings were chosen as case studies (old bazaar, Zkra, Masika, KRO, Baroshke, Tanahy, and Etite). This thesis employed a mixed methods research approach, combining qualitative and quantitative data collection methods to provide a thorough grasp of the research subject. More precisely, the quantitative part of the study entailed the methodical enumeration of vehicles and the assessment of CO₂ emissions at crucial intersections, such as the one located on 11 Ayloul Road. This approach yielded actual data on the density of traffic and levels of pollution, which serve as crucial indicators of the environmental effect and congestion in urban areas.

The quantitative data was collected in a methodical manner utilizing structured questionnaires that were carefully developed with 12 distinct questions. A total of 70 questionnaire forms were produced and distributed in seven strategically selected sites around Duhok City, guaranteeing a broad and representative sample of the people and environmental variables under investigation. Each location was not only used to distribute questionnaires but also to conduct direct observations and measurements of CO₂ emissions, giving vital empirical data for the research.

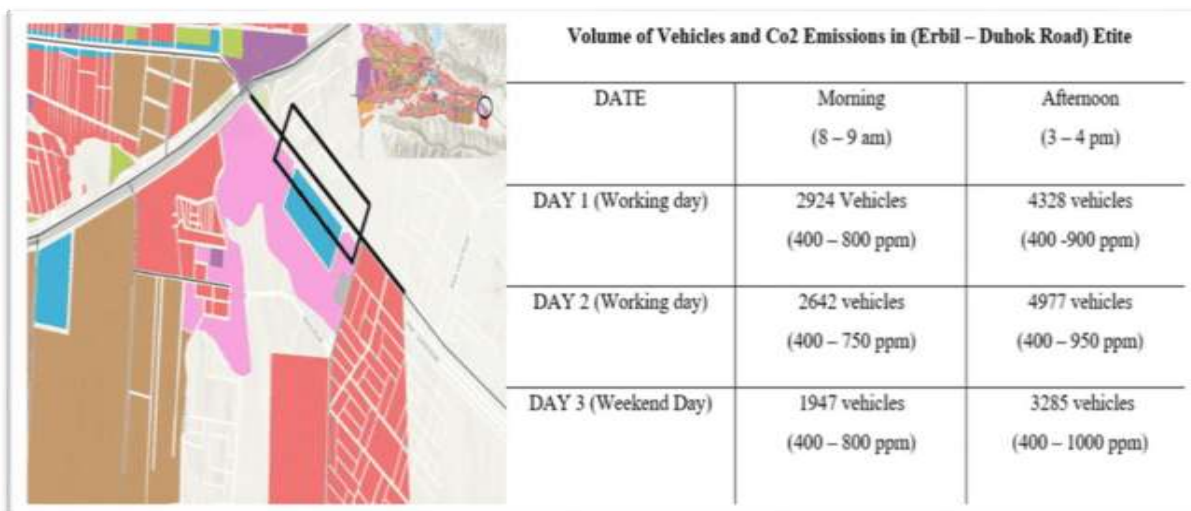
In addition, we utilized qualitative methodologies to obtain a more profound understanding of the human elements inside the urban transportation environment. Interviews were conducted with traffic police officer who operate consistently on heavily congested highways, including the bustling (11 Ayloul Road). The purpose of this interview was to investigate the health consequences of long-term exposure to vehicle emissions and excessive traffic. Through direct engagement with the police, we collected valuable anecdotal information and personal experiences, which enhanced our comprehension of the wider ramifications of pollution caused by traffic. And the second interview was with specialist in respiratory diseases The purpose of these questions was to investigate various aspects concerning the health effects of the environment. This includes examining the direct effects of CO₂ emissions on public health, gathering insights from the specialist's personal observations of health trends in the city, and obtaining professional assessments of potential long-term health scenarios. The questions also aimed to get expert perspectives on effective methods and treatments to reduce negative health consequences linked to urban environmental challenges. The interview was performed in a semi-structured fashion, providing freedom in the conversation.



This graph shows 2 specific locations in Duhok City known for frequent traffic congestion due to their connectivity with other neighborhoods and cities. These locations experience high traffic pressure and are spread throughout Duhok City. The locations are (11 Ayloul Road in Bazar Center and Duhok - Erbil Road in Elite). Which CO2 Emissions have been measured in these 2 locations and Questionnaire distributed in the same locations.



The left graph shows the map of one selected location which is old bazar (11 Ayloul Road) and the right table displays the number of vehicles and the accompanying ranges of CO2 emissions on 11 Ayloul Road in the old Bazar, categorized by different times and days. During the weekdays (Day 1 and Day 2), the number of vehicles in the afternoon was 2462 and 2625 respectively. The levels of CO2 varied between 450 and 850 ppm and 400 and 900 ppm. The evening counts for these days were lower, with 1870 and 1690 cars observed, and emissions ranged from 400 to 750 ppm and 400 to 650 ppm correspondingly. During Day 3, which was a weekend day, the number of vehicles in the afternoon traffic reached its highest point at 2860. The emissions during this time ranged from 500 to 1200 ppm, which was much higher. In the evening, the number of vehicles somewhat decreased to 1849, with emissions ranging from 400 to 850 ppm. The data reveals a notable increase in vehicle activity and emissions during the afternoon hours compared to the nighttime hours, especially on weekends. During the weekend, a significant number of cars were observed passing through the Bazar. This is attributed to the fact that weekends are popular for people to visit markets in their leisure time. The old bazaar or downtown is the oldest part of the city, primarily a shopping center with various stores. Originally, Duhok was a village centered around this area, but as the population grew, the city expanded in different directions. The data collection location is on 11 Ayloul Road, near Shorash Bridge

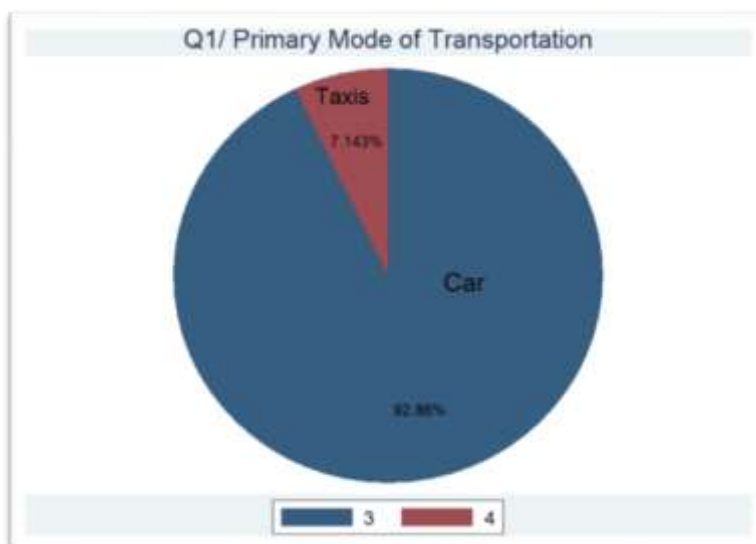


This table presents information regarding the quantity of vehicles and the amount of CO2 emissions on the Erbil-Duhok Road, which is a roadway that links two cities, for a span of three distinct days. The data is divided into two-time intervals:

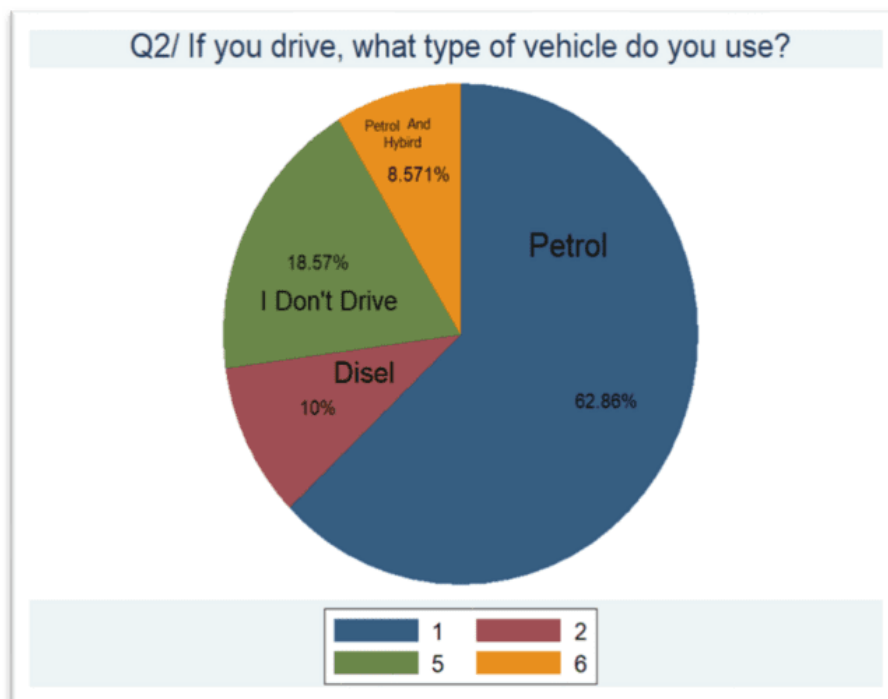
morning (8-9 am) and afternoon (3-4 pm). During the first day, which was a regular work day, the road experienced a total of 2924 cars in the morning. The levels of CO2 emissions from these vehicles ranged from 400 to 800 parts per million (ppm). In the afternoon, the traffic increased to 4328 vehicles, and the emissions ranged from 400 to 900 ppm. On the second day, there was a decline in morning traffic to 2642 cars, with emission levels ranging from 400 to 750 ppm. However, there was

a peak in the afternoon with 4977 vehicles emitting CO2 levels between 400 and 950 ppm. On the third day, which is a weekend, there is a decrease in traffic with 1947 cars in the morning (400 to 800 parts per million) and 3285 vehicles in the afternoon (400 to 1000 parts per million). This table illustrates that vehicle volumes and emissions are greater during working afternoons in comparison to mornings and weekends. The Erbil-Duhok Road serves as the primary route connecting the cities of Duhok and Erbil. This road experiences a high volume of daily traffic as it facilitates the movement of cars between the two cities. Additionally, the road provides access to various villages and rural areas surrounding Duhok and Erbil, which people frequently visit for work or to see family members. Notably, the Etite neighborhood in Duhok has witnessed significant development in recent years, this growth has resulted in the construction of numerous residential and commercial buildings in the Etite.

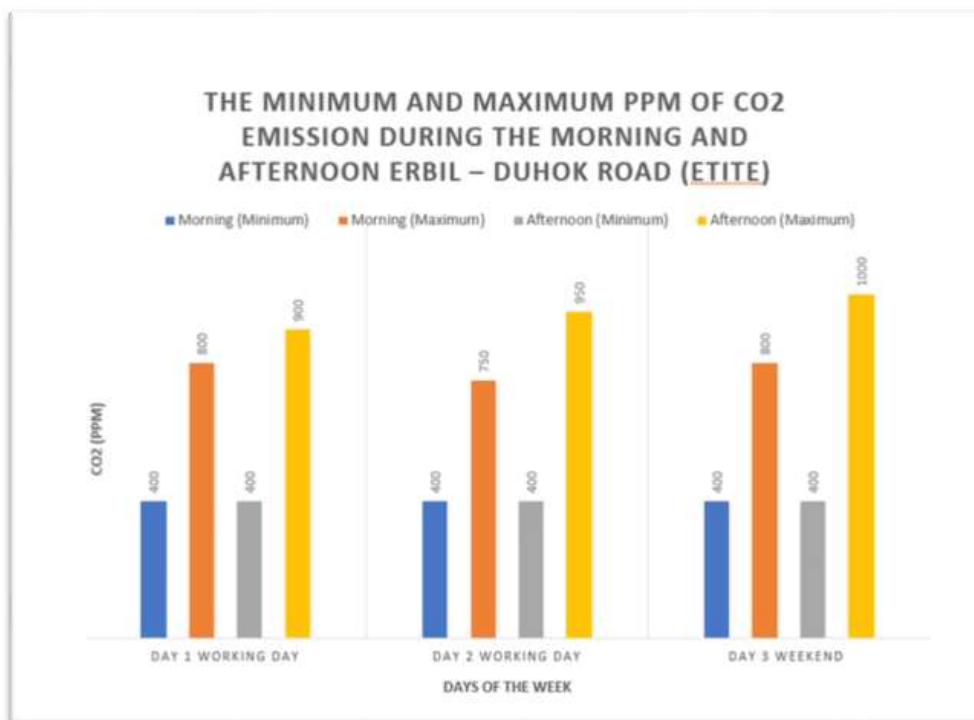
To collect data on transportation patterns and air pollution awareness, a researcher created 70 questionnaire forms and sent 10 questionnaires to each of seven carefully selected locations, chosen for their relevance to the study. The assessed sites, namely (Zrka, Masika, KRO, Bazar, Baroshke, Elite, and Tanahy). This allowed for a full analysis of different neighborhoods. The precise distribution of the questionnaires not only assured a targeted method of gathering data, but also included a varied demography that accurately represents the population's behaviors and understanding of air pollution and sustainability in their everyday commutes and travel patterns. To create a pie chart with Stata, we followed several steps. Firstly, we asked approximately 70 individuals by asking them a list of questions. Once the participants completed the questionnaire, we proceeded to analyze the data using Stata, which is a comprehensive and integrated statistical software package.



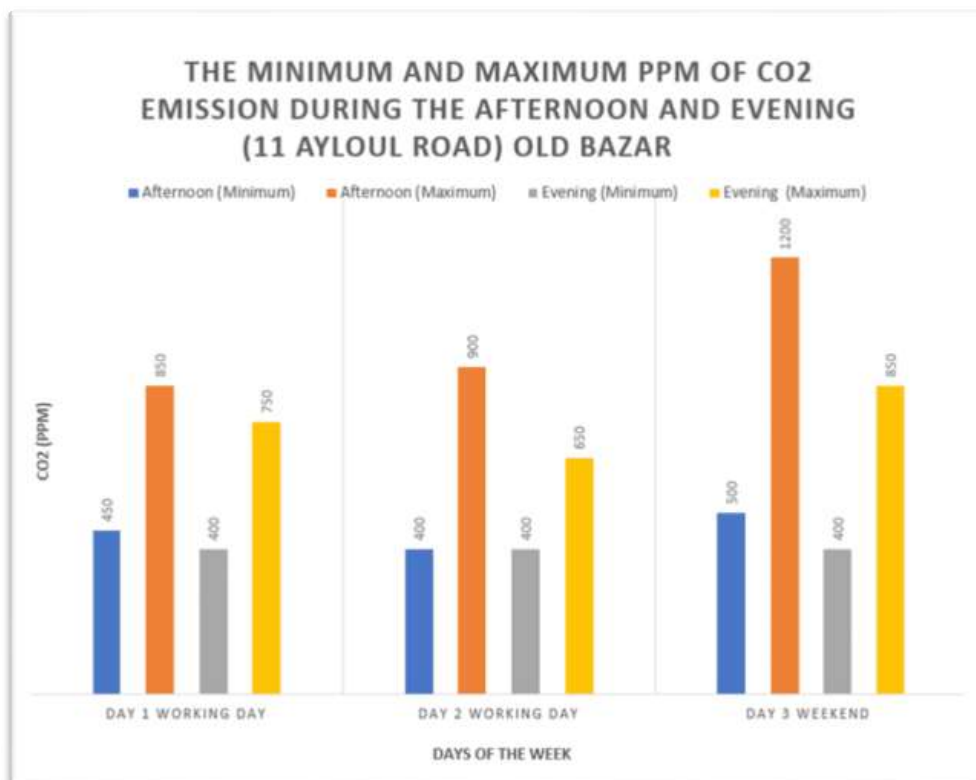
A1/ Primary Mode Of transportation: The pie chart displays data from a questionnaire on the main method of transportation used by 70 participants, indicating a notable preference for using cars. A staggering 92.86% of the participants said that they primarily rely on cars for transportation, indicating a prevalent car-centric culture among the questioned population. Only a tiny proportion, namely 7.14%, which is equal to 5 persons, said that they mostly rely on taxis. The significant disparity between the two forms of transportation highlights the limited significance of taxis as a key method of transportation for the examined population. The desire for vehicles may be ascribed to a multitude of causes, including convenience, time efficiency, personal comfort, or a dearth of sufficient public transit choices. The statistics also indicate the impact of infrastructure and cultural factors that promote the ownership and use of cars. Moreover, the dependence on private vehicles has significant consequences for environmental regulations and city development, namely for the release of CO₂, which was the main focus of the study. Elevated rates of cars use may be associated with increased emissions unless counteracted by the implementation of cleaner cars or alternative transportation alternatives.



A2/ Type of fuel for vehicle: This pie chart provides a more detailed analysis of the cars used by the 70 individuals surveyed, giving insight into their mobility preferences in terms of energy sources for their vehicles. 62.86% of respondents indicate that they use cars powered by petrol, which may be ascribed to the easy availability, affordability, and infrastructural support for petrol cars. And 10% of the respondents use diesel cars, which are renowned for their fuel economy and ability to travel great distances. This decreased share may be attributed to many variables, including the possibility of greater initial expenses, the economic and legal conditions, or a reduced choice owing to the environmental consequences of diesel emissions. Merely 8.57% of the participants own petrol-hybrid automobiles. The adoption rate, while not insignificant, indicates that hybrid technology, despite its advantages in pollution reduction and fuel efficiency improvement, has not yet been the prevailing preference among the assessed population. This may suggest the presence of obstacles such as elevated initial purchase costs, low comprehension of the advantages of hybrid technology, or inadequate incentives to influence customer preference toward hybrids. Notably, 18.57% of the participants said that they do not engage in driving. This may indicate a dependence on alternate forms of transportation, such as public transit, cycling, or walking. Alternatively, it might be due to factors such as financial limitations, physical limitations, or the absence of a need for a personal car in their lifestyle.



The graph displays the minimum and highest levels of CO2 emissions (measured in parts per million, PPM) in the morning and afternoon along (Erbil - Duhok Road) in Etite over a span of three days, consisting of two working days and one weekend day. Throughout all days, the minimum levels of carbon dioxide (CO2) stay constant at 400 parts per million (PPM) during both the morning and afternoon. The highest carbon dioxide (CO2) levels exhibit substantial variation: on Day 1 (a typical workday), the emissions in the morning reach a peak of 800 parts per million (PPM), while in the afternoon, they escalate to 900 PPM. On the second day, the level of morning emissions decreases to 750 parts per million (PPM), whereas the level of afternoon emissions increases to 950 PPM. During Day 3 of the weekend, the level of morning emissions increases to 800 parts per million (PPM), while the level of afternoon emissions sharply rises to 1000 PPM.



This graph displays the lowest and highest levels of CO2 emissions (measured in parts per million) in the afternoon and

evening at 11 Ayloul Road Old Bazar for a period of three days, consisting of two weekdays and one weekend day. The CO₂ levels for each day are categorized into four groups: Afternoon (Minimum and Maximum) and Evening (Minimum and Maximum), represented by blue, orange, grey, and yellow bars correspondingly. During weekdays, the afternoon peak levels of CO₂ reach 850 PPM and 900 PPM, however the nighttime peak levels are lower, at 750 PPM and 650 PPM. During the weekend, the highest level of particulate matter (PPM) in the afternoon reaches 1200, while in the evening it reaches 850. The minimum values of CO₂ remain reasonably stable across all days and hours, fluctuating between 400 parts per million (PPM) and 500 PPM. The graph illustrates elevated levels of CO₂ emissions throughout the afternoon, particularly on weekends, and a consistent trend during the nights.

3. Conclusion

The city of Duhok in Iraq is currently undergoing fast urbanization, resulting in a surge in the number of privately owned vehicles and putting pressure on the city's road infrastructure. This has resulted in substantial traffic congestion and air pollution, which in turn poses health risks to the residents of the city

The correlation between CO₂ emissions and public health in Duhok City is marked by both direct and indirect effects on the overall well-being of its population. Elevated concentrations of carbon dioxide (CO₂), in addition to other contaminants emitted by automobiles and industrial operations, worsen respiratory ailments and cardiovascular disorders, with a particular impact on children, the elderly, and individuals with pre-existing health concerns. Moreover, carbon dioxide (CO₂), which is a notable greenhouse gas, has a substantial role in causing global warming. This, in turn, results in heatwaves that directly endanger human health and disrupt the patterns of diseases, perhaps leading to a higher transmission of infectious diseases.

The findings from questionnaires and expert interview conducted in Duhok reveal a distinct correlation between high traffic volume, inadequate air quality, and increasing health issues. This situation is exacerbated by the city's geographical placement in a valley, which leads to the accumulation of pollutants and furthermore the majority of people heavily depend on vehicles for their everyday transportation, primarily using petrol as fuel. This is mainly because of the convenience and limited availability of reliable public transportation options. However, this reliance on cars leads to substantial emissions of CO₂. The elevated incidence of lung cancer in Duhok, as opposed to Erbil, is strongly correlated with air pollution, namely due to the inhalation of fumes emitted by poorly ventilated gasoline-powered stoves, indoor kerosene heaters, and culinary emissions. The transportation sector plays a crucial role in Duhok city as it heavily relies on the combustion of fossil fuels.

To achieve effective mitigation, it is necessary to implement integrated urban planning and policy reforms that focus on decreasing emissions and enhancing public health outcomes. While This thesis makes a substantial contribution to the existing information on urban environmental health and provides practical insights for urban planners and public health professionals in Duhok.

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