ASSESSING THE IMPACT OF ELECTRIFYING EXISTING VEHICLES IN SYLHET CITY ON CARBON EMISSION REDUCTION

A Thesis [CE 800]

by

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SYLHET ENGINEERING COLLEGE

SYLHE-3100, BANGLADESH

AUGUST, 2025

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SYLHE-3100, BANGLADESH

AUGUST, 2025

DECLARATION

I hereby declare that this thesis/project is the result of my own independent work, and to the best of my knowledge, it contains no material previously published or written by another person, nor has it been submitted for the award of any degree at Sylhet Engineering College (SEC) or any other academic institution, except where proper acknowledgment has been made. This thesis was carried out by us under the supervision of MD. Titumir Hasan.

I further affirm that the intellectual content of this work is entirely my own. Any contributions to the research by collaborators at this college or elsewhere have been clearly acknowledged.

Shaktam Singh (2019333562)

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CERTIFICATION

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ACKNOWLEDGMENT

First and foremost, praise and thanks to God, the Almighty, for his showers of blessings throughout my research work to complete the research successfully. I would like to express my deep gratitude to the MD. Titumir Hasan, workshop maintenance engineer, Department of Civil Engineering, Sylhet Engineering College, and Dr. Jahir Bin Alam, Professor, Department of Civil and Environmental Engineering, SUST, for allowing us to conduct research and provide invaluable guidance throughout this research. Their dynamism, vision, sincerity, and motivation inspired us deeply. They have taught us how to carry out the research and present the research work as clearly as possible. It was a great privilege and honor to work and study under their guidance. We are extremely grateful for what they have offered. We would also like to thank them for their friendship, empathy, and sense of humor. We extend our heartfelt thanks to their families for their acceptance and patience during the discussion we had with him on research work and thesis preparation. We are extremely grateful to our parents for their love, prayers, care, and sacrifices for educating and preparing us for the future. We are indebted to them more than they are aware of. We are very thankful to our friends for their love, understanding, prayers, and continuing support in completing this research work. We also express our gratitude to the Bangladesh Traffic Police for their support. Our Special thanks go to our co-supervisor for the keen interest in completing this thesis successfully.

Finally, we would like to thank everyone who helped and encouraged us to complete this thesis and express our apology that we could not mention individually.

Sylhet | Shaktam Singh
August, 2025 | Syeda Farhat Jaha

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ABSTRACT

Rapid motorization in Sylhet City has led to escalating CO_2 emissions, creating serious environmental and public health challenges. Our study aims to quantify the potential reduction in daily CO_2 emissions achievable through the phased adoption of electric vehicles (EVs) in Sylhet. Vehicle Kilometers Traveled (VKT) for four major vehicle categories (CNG auto-rickshaws, motorcycles, private cars, and buses) were estimated using the Average Annual Daily Traffic (AADT) and road-length data, and emissions from internal combustion engine vehicles (ICEVs) were calculated using standardized emission factors. EV emissions were derived from the electricity consumption rates and the carbon intensity of the national power grid. Scenarios with 30% and 100% fleet electrification. During (100%) ICEV operation of the selected vehicles, daily CO_2 emissions were 49,700 kg. After converting 30% of these vehicles to EV, emissions reduces to 39,983.7 kg (19.54% reduction). These findings demonstrate that even a moderate EV uptake can result in significant emission cuts. However, the magnitude of the benefits is closely tied to the grid electricity sources. Therefore, policymakers should strategize EV incentive programs to maximize climate gains in Sylhet's urban transport sector.

Chapter 1

INTRODUCTION

1.1 Background of The Study

The transportation sector is globally recognized as a major contributor to greenhouse gas (GHG) emissions. This sector is responsible for approximately 23% of the global energy-related CO_2 emissions (IEA, 2021). Road transport is a primary source of air pollution in urban areas and contributes significantly to climate change, public health risks, and declining urban livability. By the time urbanization and motorization rates increase, managing emissions from transport systems becomes critical.

This is a particularly urgent issue in Bangladesh. In urban areas, air quality deteriorates rapidly. In major cities, such as Dhaka and Chattogram, this problem is visible. The Sylhet, although smaller in scale, is not exempt. With a growing population of over 532839 (BBS, 2022) and rapid urbanization driven by remittances, tourism, and trade, Sylhet's vehicle fleet is expanding, leading to increased fuel consumption and vehicular emissions.

Electric vehicles (EVs) are known and accepted as a potential response to environmental and energy challenges compared with traditional internal combustion engine vehicles. Their adoption is increasingly seen as part of national and urban strategies to reduce greenhouse-gas emissions. In Bangladesh, discussions on EV integration have entered policy dialogues; however, their implementation, particularly in smaller cities such as Sylhet, remains limited and largely unexplored.

As urbanization and transportation demand increase over time, it is necessary to explore clean alternatives that are suitable for local conditions. For a city such as Sylhet, where the vehicle mix is diverse and dominated by smaller, fuel-dependent modes of transport, understanding how EVs can be integrated into the existing system is vital. However, such assessments require localized data, and modeling a gap this study seeks to address by evaluating real traffic emissions and estimating the CO_2 reduction potential through phased EV adoption.

Although some research has been conducted on EV deployment in Dhaka (Alam et al., 2022), mid-sized cities, such as Sylhet, remain understudied. Considering Sylhet's unique traffic dynamics dominated by CNG auto-rickshaws, motorcycles, and private cars, and the lack of emission-specific assessments, a localized analysis is necessary. Therefore, this study aimed to quantify CO_2 emissions from ICEVs and evaluate potential reductions through various EV adoption scenarios, providing valuable insights into regional decarbonization strategies.

1.2 Problem Statement

Despite Bangladesh's increasing awareness of climate change and its commitments under the Paris Agreement and updated Nationally Determined Contributions (NDCs), urban transportation remains heavily reliant on fossil fuel-based vehicles. Rapid urban growth in Sylhet has intensified traffic congestion and emissions, particularly from high-frequency vehicle types such as CNG auto-rickshaws and motorcycles. However, emission data specific to Sylhet's urban road network are scarce, which impedes data-driven policy making.

Moreover, while the government has acknowledged the importance of EVs in policies such as the Automobile Industry Development Policy (2021) and the Renewable Energy Policy (SREDA, 2020), their implementation remains limited. Specific EV targets are vague, infrastructure is underdeveloped, and public awareness is low (Nurunnahar et al., 2022). This has resulted in a disconnection between national policy aspirations and local-level transport planning.

The environmental impact of EV adoption in Sylhet has not been quantified in terms of CO_2 reduction potential under realistic traffic and grid scenarios. Without such localized studies, decisions regarding vehicle electrification, charging infrastructure, and urban mobility planning risks are misaligned with ground realities. This study addresses this gap by offering a scenario-based emissions assessment based on real traffic data and vehicle-specific fuel consumption patterns in Sylhet City.

1.3 Objective

The primary objective of this study is to evaluate the potential for CO_2 emission reduction in Sylhet City through the adoption of electric vehicles (EVs). The emissions from current internal combustion engine vehicles (ICEVs) were analyzed and compared to projected emissions under different EV adoption scenarios.

1.4 Required Steps to Achieve the Objective

1. Collect and analyze traffic volume data from major roads and intersections in Sylhet City.
2. To estimate the Vehicle Kilometers Traveled (VKT) for selected vehicle types using the AADT and road length.
3. To calculate CO_2 emissions from commonly used ICEVs (CNG auto-rickshaws, motorcycles, cars, and buses) based on fuel economy and emission factors.
4. To estimate CO_2 emissions for equivalent electric vehicle alternatives using energy consumption and grid carbon intensity data.

1.5 Research Questions

This study is guided by the following research questions:

1. What is the present level of CO_2 emissions from key vehicle types (CNG, Bike, Car, Bus) operating in Sylhet city?
2. How do emissions from electric vehicles compare with conventional ICEVs under the same traffic and road conditions?
3. What is the potential reduction in CO_2 emissions if 30% and 100% of the selected ICEVs were replaced by electric alternatives?
4. What implications do these findings have for EV-related policy planning in medium-sized urban centers, such as Sylhet?

1.6 Scope of the Study

This study focuses on Sylhet City, a medium-sized urban center in northeastern Bangladesh, characterized by growing motorization and urban congestion. It concentrates on four vehicle types (CNG auto-rickshaws, motorcycles, cars, and buses) that represent the bulk of urban road traffic and emissions. Other vehicle categories, such as trucks, lagunas, and vans, are excluded because of their limited frequency, irregular data availability, and comparatively smaller contribution to daily passenger movement.

Traffic data representing typical urban travel behavior were collected from selected high-traffic roads and intersections. Emission estimates are based solely on operational CO_2 emissions (Tank-to-Wheel for ICEVs and Well-to-Wheel for EVs) and do not include manufacturing or disposal-related emissions. Owing to limited local emission factor data, regionally or internationally standardized values were used. The study further modeled three electrification scenarios to estimate the emission reduction potential under increased EV adoption.

1.6 Significance of the Study

CO_2 emissions from urban transportation are a growing environmental and public health concern in Bangladesh. Most emissions research in the country is concentrated in Dhaka, while smaller yet rapidly growing cities, such as Sylhet, have received very limited attention. Localized emission estimates were addressed based on real traffic data, and the possibility of improving air quality by transitioning to electric mobility was explored.

In addition, the activities of different vehicles at different locations in the city can be determined. The study also showed the environmental impact of different vehicles (four vehicles were selected) by estimating the emissions of each vehicle. Therefore, in the near future, if there are any programs related to GHG reduction, appropriate measures can be taken. The results of this study can inform local and national transport planning, support targeted policies for EV integration, and contribute to Bangladeshi broader climate commitment. It also provides a replicable framework for other mid-sized cities that face similar challenges.

Chapter 2

LITERATURE REVIEW

2.1 General

The transportation sector is one of the major contributors to greenhouse gas (GHG) and air pollutant emissions, which may intensify interest in reducing both simultaneously (Fan et al., 2018). There are some solutions; however, Electric Vehicles (EVs) can be considered a key solution to decarbonize transportation. It also enhances environmental sustainability owing to its lower greenhouse gas (GHG) emissions and reduced fossil fuel consumption. Unfortunately, the environmental advantages of EVs are not only due to their zero tailpipe emissions but are also significantly affected by the carbon intensity of the electricity grid from which they draw power or charge (Ghosh, 2020). Another piece of information is the location of battery manufacturing, especially if far from where the vehicle is used, which can also influence pollution reduction benefits (Vidhi & Shrivastava, 2018).

2.2 Scope and Structure of this Review

This review includes existing research on emissions from Internal Combustion Engine (ICE) vehicles compared to Electric Vehicles (EVs), with an examination of the role of grid carbon intensity. While this is a specific case study for Sylhet, Bangladesh, it is also part of a broader research effort. This review focuses on established global findings from India, Ireland, China, and Poland, as presented in the cited literature. The primary gas discussed is carbon dioxide (CO2), although after burning fuels, vehicles also produce air pollutants such as nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and sulfur dioxide (SO2).

In this review, first defined and compared the emissions from ICEVs and EVs, including key methodologies. The critical role of grid carbon intensity is then discussed, followed by a synthesis of comparative studies from the literature.

2.3 Vehicle Emissions: Methodologies and Metrics

2.3.1 Emissions from Internal Combustion Engine (ICE) Vehicles

ICE vehicles can be considered the primary sources of greenhouse gases and other air pollutants such as CO2, NOx, PM, CO, and SO2 in Sylhet City. These emissions are affected by the type of fuel used (e.g., LPG, CNG, petrol, diesel, and hydrogen) (Laskowski et al., 2024). Most of the emissions come from daily operations, which is also known as tank-to-wheel (TTW) emissions. In other words, TTW emissions refer to pollutants directly released from a vehicle's tailpipe during operation, also known as operational emissions. In fact, it is true that manufacturing a vehicle also produces CO2. In this study, focused on operational emissions.

2.3.2 Emissions from Electric Vehicles (EVs)

EVs are known to exhibit zero tailpipe emissions. However, their overall environmental impact, particularly that of CO2, depends completely on the electricity generation process. Electricity generation, transmission, and distribution emit GHG, which is considered in the EVs' Well-to-Wheel (WTW) concept. This implies that EV reduce pollution only if a high percentage of the electricity mix comes from renewable sources (Ghosh, 2020). Battery manufacturing can also contribute to air pollution, even if it is located far from the vehicle usage area (Vidhi et al., 2018).

2.3.3 Key Methodologies for Emission Assessment

Studies on environmental sustainability have widely used the greenhouse gas emissions footprint and global warming potential. The methodologies used to assess vehicle emissions include Life Cycle Assessment (LCA), tank-to-wheel (TTW), and well-to-wheel (WTW) analysis. Evaluating air quality due to emissions, particularly in transportation, may involve assessing the limitations of the current methods (Fan et al., 2018). In our methodology, Vehicle Kilometers Traveled (VKT) are involved. The VKT is a fundamental metric for calculating transportation emissions and helps determine the net benefits of EV adoption (Smith, 2010).

Another important parameter is Emission factor (EF). With this critical input, the amount of CO_2 or other pollutants can be quantified per unit of fuel consumed or the distance traveled. These are typically expressed as grams of pollutant per kilometer (g/km) or per liter of fuel burned (g/L) and vary by fuel-to-fuel, engine condition, and driving pattern (IPCC, 2006).

2.4 The Critical Role of Grid Carbon Intensity

The grid carbon intensity, also known as the electricity emission factor, represents the amount of CO_2 equivalent emissions per unit of electricity generated (gm CO_2e/kWh) (Ghosh, 2020). This directly reflects the energy mix used for the electricity generation.

2.4.1 Regional and Temporal Variability of Grid Carbon Intensity

A key finding of this study is that the benefits of EVs are highly dependent on the characteristics of the electricity generation and distribution systems (Ghosh, 2020). For instance, in Poland, because of the heavy reliance on coal to generate electricity, the emissions from EV are equivalent to those from regular vehicles (Laskowski et al., 2024). Conversely, EVs in regions with a high percentage of renewable energy in their electricity mix show a greater pollution reduction (Ghosh, 2020). In Bangladesh, the substantial power demand for recharging EV batteries significantly impacts the power grid and distribution networks, while EV penetration is increasing (Karmaker et al., 2019). Bangladesh's power grid mainly relies on gas, oil, and coal.

2.4.2 Impact of Grid Carbon Intensity on EV Emissions

When the grid carbon intensity is high, natural EVs charging on the grid power emits higher CO_2 gas, which diminishes or even negates the CO_2 reduction benefits of EVs (Ghosh, 2020). Therefore, the net environmental benefit of EVs directly depends on the carbon intensity of the electricity grid. Conversely, a cleaner grid (lower carbon intensity) leads to lower well-to-wheel emissions for EVs, thereby maximizing their environmental advantages.

2.5 Comparative Studies of ICE and EV Emissions in Literature

2.5.1 Methodological Approaches in Comparative Studies

Studies comparing pollutant emissions from various vehicle types, including Battery Electric Vehicles (BEVs) or EV, internal combustion engine vehicles (ICEVs), and Hybrid Vehicles (HV), often focus on how different fuel types and the national grid energy mix affect emissions, such as CO_2, NO_x, PM, CO, and SO_2.

Some studies have also used mathematical simulations to illustrate the impact of fuel type on pollutant emissions (Laskowski et al., 2024).

For accurate emission simulation, researchers often employ advanced tools, such as simulation software, to determine the CO2 intensity. For example, a researcher evaluated the impact of introducing electric vehicles (EVs) into a smart grid using the AVL Cruise software. The simulation of vehicles operates under the New European Driving Cycle (NEDC) to calculate emissions, fuel consumption, and efficiency (Teixeira et al., 2018). Another study utilized a Life Cycle Assessment (LCA) approach to estimate CO2 emissions. However, this study only considered two cars (ICEV and EV) (Kawamoto et al., 2019).

So far Well-to-wheel (WTW) analysis is a commonly used method for estimating the air pollution impact of electrification (Liu et al., 2021), (Inderwildi et al., 2010), (Casals et al., 2016). These studies are mostly conducted using either Cars or Buses because that is what is usually found in their respective countries. A study in Dhaka estimated the impact of EVs while considering only four ICEV cars (Rasheduzzaman et al; 2022).

2.5.2 Methodological Approaches in Our Studies

Employed a Tank-to-Wheel (TTW) analysis for ICEVs, focusing on mixed traffic scenarios typical of Sylhet City. ICEVs, including CNG-powered auto-rickshaws, are the most common type of public transport in Sylhet City. They are found in large numbers, including in Motorcycles, Cars and Buses. To assess emissions by estimating Vehicle Kilometers Traveled (VKT) per day for each type of ICEVs. A study was conducted in Khon Kaen City, Thailand, aiming to estimate Vehicle Kilometers Traveled (VKT) by vehicle type using a method based on odometer records and driver interview surveys (Fukuda, 2013). In a similar study in Dhaka, the average VKT of distance travelled annually by a car (12,100 km) (Rasheduzzaman et al; 2022). However, in our case, we used the FHWA (2018) guidelines to determine VKT using Annual Average Daily Traffic (AADT). With the fuel efficiency and VKT of the respective vehicles, we calculated the CO2 intensity for both ICEVs and EVs (considering the grid carbon intensity). To maintain realistic comparisons, we selected specific EV models that closely matched the sizes and performances of their ICE counterparts.

In this study, EFs were adopted from (Schlömer et al., 2014), who provided internationally or regionally relevant values for different vehicle types, including CNG auto-rickshaws, motorcycles, and buses.

2.5.3 Key Findings on Emission Comparisons

Transitioning to EVs, including Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV), offers the potential for significant emission reductions (Jiao et al., 2020). A study in Guangzhou, China quantitatively analyzed the co-benefits of reducing CO2 and air pollutant emissions in the urban transport sector. Adjusting transport modes and increasing the application of electricity are the two most effective measures for achieving these co-benefits (Jiao et al., 2020). Therefore, these measures are highly effective at mitigating CO2 and air pollutant emissions.

2.5.4 Factors Influencing Comparative Outcomes

Beyond grid carbon intensity, factors influencing emission outcomes include the proportion of vehicle-kilometers completed under electric power (Smith, 2010). The overall benefits of EV adoption depend on technological improvements and government support (Ahmed, 2019). In addition, it is necessary to make EVs popular with the public. However, the expansion of EV markets and the integration of charging stations with the utility grid can produce harmonics and affect voltage profiles, thereby impacting power quality owing to increased power demand for recharging batteries (Karmaker et al., 2019). Despite its benefits, the adoption of EVs in Bangladesh faces several barriers. This includes the lack of infrastructure, public awareness, and charging stations.

2.6 Discussion and Policy Implications

2.6.1 Synthesis of Findings

Decarbonizing the transport sector through EVs is considered an environmentally beneficial and efficient solution to combat global climate change and move towards sustainable mobility (Ghosh, 2020). The effectiveness of electric vehicles (EVs) in reducing pollution is maximized when the electricity they use is generated from a high percentage of renewable sources, as their environmental benefits are directly tied to the carbon intensity of the power grid.

2.6.2 Implications for Policy and Planning

Governments play a crucial role in promoting EV adoption through supportive policies and incentives (Vidhi et al., 2018). For example, the Indian government has an ambitious policy to switch 100% of light-duty consumer vehicles to electric vehicles by 2030, relying on vehicle-grid interaction and shared mobility through EV fleets (Kaur, 2022). Policies are also required to overcome the challenges of EV penetration (Ahmed, 2019). The Bangladeshi government has acknowledged the potential of electric vehicles to reduce emissions and fuel dependence. This is reflected in policy frameworks such as the Automobile Industry Development Policy (2021). The decision to ban electric three-wheelers in Bangladesh while aiming to improve road safety could exacerbate economic crises if alternative income sources are not provided (Nurunnahar et al., 2022).

2.6.3 Limitations of the Overall Review

A significant gap identified in some assessments is that greenhouse gases and air pollutants are not evaluated simultaneously, and the interaction between different pollutants is not adequately considered (Fan et al., 2018). The current assessments of air emissions, particularly in transportation, have limitations. For EVs, challenges to widespread uptake include the need for technological improvements and government support as well as issues related to power quality due to charging stations (Ahmed, 2019; Karmaker et al., 2019).

Accurate emission estimations depend on the use of context-specific EFs; however, in Bangladesh, local emission factor datasets are limited, leading researchers to adopt values from regional or international studies (Schlömer et al., 2014). While a complete citywide road network analysis was beyond the scope of this study, the selected segments were among the busiest in Sylhet and were chosen based on their high vehicular volume, functional classification, and central role in intra-city mobility. This study focuses on four major vehicle types that dominate the urban traffic flow in Sylhet: buses, cars, CNG auto-rickshaws, and motorcycles. Other vehicle categories, including trucks, lagunas, and vans, were excluded because of their comparatively low frequency, irregular availability of reliable data, and minimal contribution to daily passenger movement. As a result, the CO_2 emission estimation presented in this study is limited to these selected vehicle types, and may not fully capture emissions from the entire urban fleet.

2.7 Summary

The key literature on transport-related CO_2 emissions, emission factors, VKT estimations, and the potential of electric vehicles were reviewed. Found that, while EVs offer notable emission reductions, the actual benefit depends on the grid carbon intensity and local driving conditions. Bangladesh-specific research in this field remains limited, especially for cities such as Sylhet.

Existing government policies support EV adoption; however, gaps remain in infrastructure, local emission data, and implementation strategies. The reviewed methods and findings provide a foundation for this study's emission analysis, which focuses on the four major vehicle types in Sylhet.

Chapter 3

METHODOLOGY

3.1 Overview

This chapter outlines the methodological approach undertaken to estimate CO_2 emissions from the current vehicle fleet operating in Sylhet City and assesses the potential reductions achievable through the adoption of electric vehicles (EVs). The methodology included a systematic framework comprising traffic volume surveys, vehicle classification, AADT and VKT calculations, and emission estimations based on standard emission factors. It also incorporates scenario modeling to project CO_2 emission reductions under varying levels of EV penetration (e.g., 30%, 40%, and 50%).

This study relies on both primary and secondary data sources. Primary data were collected through field surveys and traffic counts at key road segments in Sylhet, while secondary data, such as vehicle fuel economy, emission factors, and electricity grid data, were obtained from national reports and international guidelines (e.g., IPCC, SREDA). The procedures and tools used in each step are described in detail in the following section.

3.2 Proposed Framework

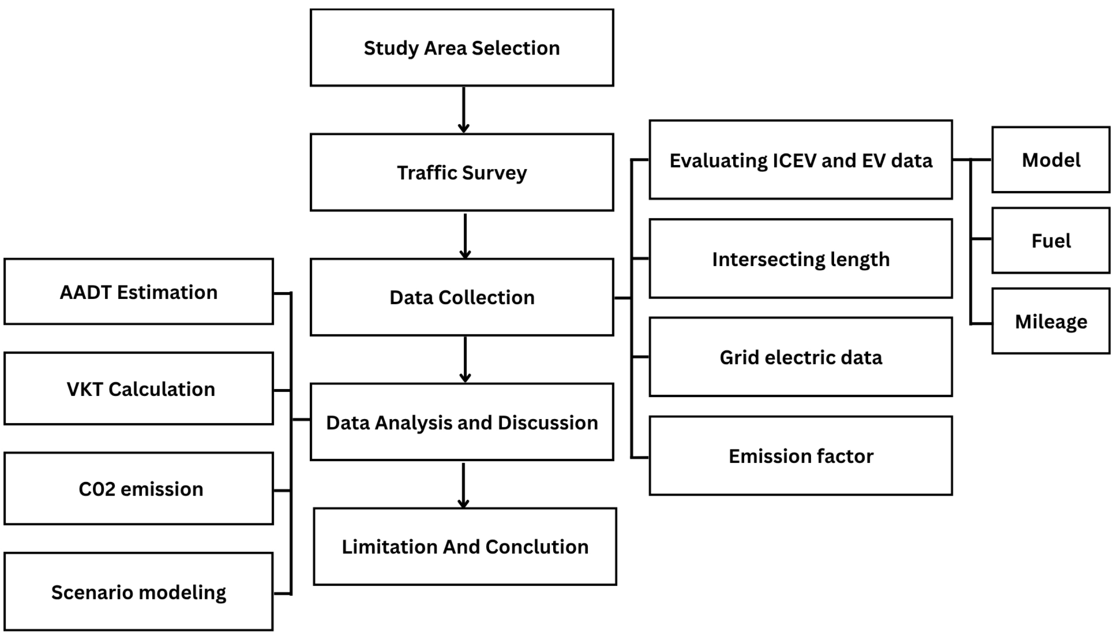

Figure 1: Methodology Workflow

3.3 Study Area Selection

3.3.1 Geographical Scope

Sylhet City, situated in northeastern Bangladesh, serves as the study area for this research on CO_2 emission reduction through electric vehicle (EV) adoption. As the administrative capital of the Sylhet Division, the city spans approximately 26.5 km^2, with a mixed topography of flat and hilly areas influencing its road network. The population is estimated to be 532,839 in 2022, with a density of 6,702 persons/km^2 (BBS, 2022). The local economy thrives on trade, tourism, and remittances, contributing to growing urban mobility needs. Sylhet's transport system includes a diverse mix of motorized (CNG auto-rickshaws, motorcycles, buses, trucks, and private cars) and non-motorized vehicles (rickshaws and bicycles).

3.3.2 Justification for Choosing Sylhet

Sylhet faces significant traffic congestion in commercial hubs, such as Zindabazar and Bondar-Bazar. The high density of CNG auto-rickshaws and motorcycles increases fuel consumption and emissions owing to idling and stop-and-go traffic. Rising vehicle numbers, with Bangladesh's registered vehicles growing from 188036 in 2011 to 445030 in 2021 (BRTA, 2020), reflect similar trends in Sylhet, making it a critical case for emission reduction. As one of Bangladesh's fastest-growing cities, Sylhet has seen an urban population increase of approximately 4% annually (BBS, 2023), intensifying transport demand and associated CO_2 emissions. Sylhet's transport sector is diverse, with a mix of CNG auto-rickshaws, petrol-powered motorcycles, private cars, and diesel buses. This variety allows for a comprehensive analysis of the EV adoption across different vehicle classes. For instance, CNG auto-rickshaws, which dominate short-distance urban trips, are prime candidates for electrification owing to their high daily mileage and emission contributions. The diversity of vehicles provides a robust testing ground for evaluating the scalability and impact of EVs.

Most emission studies in Bangladesh focus on Dhaka, leaving mid-sized cities such as Sylhet understudied despite facing similar or emerging transport challenges. With short intra-city travel distances, Sylhet is well-suited for EVs. Its history with alternative fuels (e.g., CNG) and the growing renewable share of the national grid (3.5% solar, BPDB, 2025) further support the feasibility of EV deployment.

This combination of practical challenges and favorable conditions makes Sylhet a relevant and timely case for evaluating the environmental benefits of EV adoption.

3.4 Traffic Survey and Data Collection

3.4.1 Traffic Volume Count

Traffic volume data were collected from 12 major intersections and road segments across Sylhet City to estimate vehicle activity and the corresponding CO_2 emissions. These locations include Ambarkhana, Tilagor, Chowhatta, Bondar, Naiorpul, Upashahar, Humayun-Chattar, Majortila, Airport Road, Subid-Bazar, Modina-Market and Zindabazar. These sites were selected based on their high traffic intensity, strategic importance to urban mobility, and diversity of observed vehicle types.

Traffic counts were conducted during weekday peak hours (9:00–10:00 AM, 1:00–2:00 PM, and 4:00–5:00 PM) in February 2025, using a combination of manual counting and video recording techniques. Vehicles were categorized into types, such as buses, CNG auto-rickshaws, motorcycles, and private cars, to support downstream VKT and emissions calculations.

For a few locations, corridors such as Kamran-Chattar to Bondar, Chowhatta to Bondar, Airport Road to Ambarkhana, Tilagor to Ambarkhana, Subid-Bazar to Ambarkhana, and Chowhatta to Ambarkhana were obtained from a previous traffic study conducted by [Emon et al., 2024], which used a comparable peak-hour survey method within a similar temporal and spatial framework. These segments were included to ensure broader network coverage and to maintain methodological consistency while addressing logistical constraints during fieldwork.

All collected data were organized and processed using Microsoft Excel, forming the basis for calculating vehicle activity metrics and estimating CO_2 emissions from the city's transport sector.

3.4.2 Vehicle Type Classification

This study focused on four major vehicle types that dominate Sylhet's urban traffic: CNG auto-rickshaws, motorcycles, private cars, and buses. These vehicle categories were selected because of their high frequency of use, availability across most urban routes, and significant contribution to the daily passenger movement and traffic emissions. Other vehicle categories including trucks, lagunas, and vans were excluded for several reasons. These vehicles are less frequent, often operate on irregular or specialized routes, and primarily serve commercial or goods transport functions. Moreover, the lack of reliable data and the limited availability of electric alternatives for these categories in the local context make their inclusion in EV modeling challenging. Replacing such vehicles with electric versions is also technically and economically more complex, especially given the higher upfront costs, range limitations, and lack of suitable EV models currently available in Bangladesh.

Consequently, this study limits its CO_2 emissions to the most commonly used and practically viable vehicle types for electrification in Sylhet's urban environment.

3.5 Other Data Collection

To ensure an accurate and comprehensive estimation of CO_2 emissions and potential reductions through electrification, several additional datasets were collected and compiled:

3.5.1 Vehicle Models and Fuel Types

Vehicle types observed in the field were categorized based on their common usage in Sylhet and confirmed through driver interviews and visual surveys. The most prevalent models are as follows.

CNG Auto-Rickshaws: Common models include Bajaj RE, TVS King, and Piaggio Ape, which all operate on compressed natural gas (CNG).

Motorcycles: Some models include Suzuki Gixxer, TVS Victor, and Bajaj Discover, running on petrol.

Cars: Models such as Toyota Corolla, Toyota Noah, Suzuki Wagon, and Toyota Hiace were frequently observed. These use a mixture of petrol and bi-fuel (petrol + CNG), with some hybrid variants also present. It was observed that bi-fuel is the most common fuel type for cars in Sylhet.

Buses: Primarily diesel-powered inter- and intra-city models, such as Hino AK and Tata LP.

(Mileage values along with model lists are compiled in **Appendix B.**)

3.5.2. Mileage (Fuel Economy)

The average mileage (fuel consumption per kilometer) for each vehicle type and model was collected from a combination of driver-provided estimates (during interviews), manufacturer specifications, and online automotive platforms such as review websites and product listing pages.

Online data were used to cross-validate the self-reported mileage and ensure consistency across vehicle models. This method is commonly adopted in transport research when local dynamo-meters or test-track data are unavailable.

(Mileage values along with model lists are compiled in **Appendix B.**)

3.5.3. Electric Vehicle (EV) Model Selection

To estimate the emissions of electric vehicles, representative EV models were selected for each vehicle class. Examples include:

1. **Electric CNG replacement**: Palki Cityboy V3, TVS King EV Max etc.
2. **Electric motorcycles**: Revoo models, Energica Ego etc.
3. **Electric private cars**: Nissan Leaf, BYD atto 3 etc.
4. **Electric buses**: BYD K9 etc.

The energy consumption data for these EVs were collected from the manufacturer websites, technical data-sheets, and vehicle review portals.

Appendix (presents the model and mileage data are presented in **Appendix B**.)

3.5.4. Electricity Grid Data for EV Charging

To assess the emissions from EV usage, electricity grid characteristics were incorporated. The grid fuel mix data were collected from the Bangladesh Power Development Board (BPDB, 2024). The energy mix consists of approximately 44.35% gas, 26.18% coal, 20.57% from oil, and 3.62% renewable sources.

3.5.5. Emission Factors

CO_2 emission factors for CNG, petrol, diesel, and the grid electricity mix were compiled from peer-reviewed international literature, primarily based on the IPCC Guidelines for National Greenhouse Gas Inventories and supporting data from the IPCC Fifth Assessment Report. Specifically, the values were referenced from Annex

III: Technology-specific Cost and Performance Parameters, which provide life-cycle emission intensities for various energy sources (Schlömer et al., 2014). Given the limited availability of Bangladesh-specific emission testing data, these standardized international benchmarks serve as a consistent and scientifically robust basis for emission comparisons across fuel types.

(All emission factors used in calculations are listed in **Appendix C**.)

3.6 Estimation of Average Annual Daily Traffic (AADT)

The Average Annual Daily Traffic (AADT) was calculated based on the observed peak-hour traffic data to estimate the total daily traffic for various road segments in Sylhet.

Traffic volume counts were conducted during the three typical weekday peak periods. In the morning (9:00–10:00 AM), midday (1:00–2:00 PM), and evening (4:00–5:00 PM).

From these, the time period with the highest peak our factor (PHF) (indicating the least variability and most stable traffic flow) was selected as the basis for the AADT estimation. This approach helps to reduce potential errors caused by irregular traffic surges or dips.

The formula used is:

AADT = Observed Peak Hour Volume × HEF × WEF × MEF

Equation is derived from (Al Maaiteh et al., 2019)

3.6.1 Use of Expansion Factors

To convert peak-hour counts into AADT, Hourly Expansion Factors (HEF), Weekly Expansion Factors (WEF), and Monthly Expansion Factors (MEF) were applied. These factors account for the variations across days, weeks, and years.

Owing to the absence of Bangladesh-specific expansion factors, values from a published study conducted in Amman, Jordan (Maaiteh et al., 2018) were adopted. The justification for this choice is as follows: Like Sylhet, Amman is a densely populated urban area in a developing country. As a major Muslim country, Jordan shares a similar weekend structure (Friday and Saturday), helping align weekday traffic patterns. No long-term or hourly classified count data were available for

Sylhet, making Jordanian factors a reasonable proxy under limited resource conditions. These expansion factors were carefully applied to maintain consistency with the temporal distribution of traffic in the Sylhet context.

3.7 Vehicle Kilometer Traveled (VKT) Calculation

Vehicle kilometers Traveled (VKT) were estimated using the product of the Average Annual Daily Traffic (AADT) and the length of the corresponding road segments for each selected location. The formula used is:

VKT = AADT × Road Length

Equation from **(**FHWA, 2018)

Only 12 major road segments within Sylhet were included in this calculation. These roads were selected based on their high traffic density, importance for daily commuting, and representation of broader urban traffic patterns. The selection ensures that the VKT estimates reflect typical vehicle movements within the city.

It was assumed that all the recorded vehicles traveled the full length of the road segments where the counts were taken. Although this may not capture partial trips or deviations, it provides a consistent and standardized approach for estimating the total distance traveled. This assumption aligns with similar methodologies used in urban transport emission studies, where detailed trip-level data are unavailable (FHWA, 2018).

(The section length of each road is provided in **Appendix E**).

3.8 CO_2 Emission Estimation

The estimation of CO_2 emissions in this study was conducted separately for each of the four selected vehicle categories: CNG autorickshaws, motorcycles, private cars, and buses. Standard emission calculation methods were used for both Internal Combustion Engine Vehicles (ICEVs) and Electric Vehicles (EVs), allowing a comparative analysis across modes.

3.8.1 ICEV Emissions

CO_2 emissions from ICEVs were calculated using the Vehicle Kilometer Traveled (VKT) for each vehicle type, multiplied by the corresponding emission factor (EF), and expressed in grams of CO_2 per kilometer (gCO_2/km). The formula used is:

ICEV Emissions = VKT × EF / Fuel Efficiency

Equation from **(**Kaur, 2018)

Emission factors were selected based on fuel type : CNG, petrol, and diesel.

3.8.2 EV Emissions

For EVs, emissions were estimated based on the electricity consumption and carbon intensity of the national grid. The calculation formula is as follows:

EV Emissions = VKT × Grid EF / Fuel Efficiency

Equation from **(**Kaur, 2018)

Electric energy consumption data (kWh/km) for different EV models were gathered from manufacturer specifications and cross-verified through online review platforms.

Each of the four vehicle types was analyzed independently for both the ICEV and EV scenarios, ensuring that the emission estimates reflected the distinct operational characteristics and energy consumption patterns of each mode. This dis-aggregated approach provides a clearer understanding of sector-specific contributions to CO_2 emissions and the potential impacts of targeted electrification.

3.9 Scenario Modeling

To assess the potential reduction in CO_2 emissions through the adoption of electric vehicles (EVs), three hypothetical adoption scenarios were developed: 30% and 100% electrification of the existing selected vehicle fleet in Sylhet City. Each scenario assumes that the same proportion of current Internal Combustion Engine Vehicles (ICEVs) will be replaced by EVs across all four vehicle categories: buses, cars, CNG auto-rickshaws, and motorcycles.

Under each scenario, the VKT values for ICEVs were proportionally reduced and the corresponding VKT was reassigned to EVs (Wu et al, 2012). Emissions for the remaining ICEVs were calculated using the conventional method (VKT × EF/Mileage), whereas emissions for the EVs were estimated using the energy consumption per kilometer multiplied by the grid emission factor.

The scenario results were compared with the baseline emissions (i.e., emissions from 100% ICEV operation) to determine the relative CO_2 reduction achieved under each adoption level.

Chapter 4
RESULTS AND DISCUSSION

4.1 Calculation for AADT

4.1.1 Analysis for Traffic Volume on Modina-Market to Subid-Bazar Road

On February 27, 2025, collected data for three different hours: 9:00 AM, 1:00 PM, and 4:00 PM.

Table 1: Traffic Data for 9:00 AM Modina-Market to Subid-Bazar Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1342	569	333	25	19
PCE	0.75	0.5	1	3	3
PCU	1006	284	333	75	57

So, Flow rate = 1006 + 284 + 333 + 75 + 57 = 1755 PCU/hr

Therefore, the Peak Hour factor was (PHF) = 1755 / (6 × 327) = 0.894.

Table 2: Traffic Data for 1:00 PM Modina-Market to Subid-Bazar Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1569	650	336	32	29
PCE	0.75	0.5	1	3	3
PCU	1177	325	336	96	87

So, Flow rate = 1177 + 325 + 336 + 96 + 87 = 2021 PCU/hr

Therefore, the Peak Hour factor (PHF) = 2021 / (6 × 375) = 0.898.

Table 3: Traffic Data for 4:00 PM Modina-Market to Subid-Bazar Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1830	653	330	34	31
PCE	0.75	0.5	1	3	3
PCU	1372	326	330	102	93

So, Flow rate = 1372 + 326 + 330 + 102 + 93 = 2223 PCU/hr

Therefore, the Peak Hour factor (PHF) was 2223 / (6 × 411) = 0.901.

Maximum PHF is 0.901 at 4PM with flow rate of 2223 PCU/hr

Annual Average Daily Traffic = Flow rate x HEF x WEF x MEF

= 2223×14.6157×1.073×1.034 (4pm, Sat, Feb)

= 36048 PCU/ Day

4.1.2 Analysis for Traffic Volume on Tilagor to Majortila Road

On February 18, 2025, collected data for three different hours: 9:00 AM, 1:00 PM, and 4:00 PM.

Table 4: Traffic Data for 9:00 AM Tilagor to Majortila Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	829	506	199	35	37
PCE	0.75	0.5	1	3	3
PCU	622	253	199	105	111

So, Flow rate = 622 + 253 + 199 + 105 + 111 = 1179 PCU/hr

Therefore, the Peak Hour factor (PHF) = 1179 / (6 × 268) = 0.8.

Table 5: Traffic Data for 1:00 PM Tilagor to Majortila Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1304	660	331	61	40
PCE	0.75	0.5	1	3	3
PCU	978	330	331	183	120

So, Flow rate = 978 + 330 + 331 + 183 + 120 = 1942 PCU/hr

Therefore, the Peak Hour factor (PHF) = 1942 / (6 × 376) = 0.86.

Table 6: Traffic Data for 4:00 PM Tilagor to Majortila Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1250	683	228	53	50
PCE	0.75	0.5	1	3	3
PCU	937	341	228	159	150

SSo, Flow rate = 937 + 341 + 228 + 159 + 150 = 1815 PCU/hr

Therefore, the Peak Hour factor (PHF) is 1815 / (6 × 345) = 0.877

Maximum PHF is 0.877 at 4PM with flow rate of 1815 PCU/hr

Annual Average Daily Traffic = Flow rate x HEF x WEF x MEF

= 1815×14.6157×0.954×1.034 (4pm, Tue, Feb)

= 26168 PCU/ Day

4.1.3 Analysis for Traffic Volume on Tilagor to Naiorpul Road

On February 26, 2025, collected data for three different hours: 9:00 AM, 1:00 PM, and 4:00 PM.

Table 7: Traffic Data for 9:00 AM Tilagor to Naiorpul Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1146	442	141	30	26
PCE	0.75	0.5	1	3	3
PCU	859	221	141	90	78

So, Flow rate = 859 + 221 + 141 + 90 + 78 = 1299 PCU/hr

Therefore, Peak Hour factor (PHF) = 1299 / (6 x 268) = 0.808

Table 8: Traffic Data for 1:00 PM Tilagor to Naiorpul Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	962	434	132	32	15
PCE	0.75	0.5	1	3	3
PCU	721	217	132	96	45

So, Flow rate = 721 + 217 + 132 + 96 + 45 = 1211 PCU/hr

Therefore, Peak Hour factor (PHF) = 1211 / (6 × 240) = 0.84.

Table 9: Traffic Data for 4:00 PM Tilagor to Naiorpul Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	918	456	163	36	23
PCE	0.75	0.5	1	3	3
PCU	688	228	163	108	69

So, Flow rate = 688 + 228 + 163 + 108 + 69 = 1256 PCU/hr

Therefore, Peak Hour factor (PHF) is 1256 / (6×240) = 0.872

Maximum PHF is 0.872 at 4PM with flow rate of 1256 PCU/hr

Annual Average Daily Traffic = Flow rate x HEF x WEF x MEF

= 1256×14.6157×0.958×1.034 (4pm, Wed, Feb)

= 18678 PCU/ Day

4.1.4 Analysis for Traffic Volume on Upashahar to Humayun-Chattar Road

On February 19, 2025, collected data for three different hours: 9:00 AM, 1:00 PM, and 4:00 PM.

Table 10: Traffic Data for 9:00 AM Upashahar to Humayun-Chattar Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1208	650	311	27	45
PCE	0.75	0.5	1	3	3
PCU	906	325	311	81	135

So, Flow rate = 906 + 325 + 311 + 81 + 135 = 1758 PCU/hr

Therefore, Peak Hour factor (PHF) = 1758 / (6 × 318) = 0.92

Table 11: Traffic Data for 1:00 PM Upashahar to Humayun-Chattar Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1290	648	273	29	25
PCE	0.75	0.5	1	3	3
PCU	967	324	273	87	75

So, Flow rate = 967 + 324 + 273 + 87 + 75 = 1726 PCU/hr

Therefore, Peak Hour factor (PHF) = 1726 / (6 × 338) = 0.85

Table 12: Traffic Data for 4:00 PM Upashahar to Humayun-Chattar Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1614	791	419	41	72
PCE	0.75	0.5	1	3	3
PCU	1210	395	416	123	216

So, Flow rate = 1210 + 395 + 416 + 123 + 216 = 2363 PCU/hr

Therefore, Peak Hour factor (PHF) = 2363 / (6 × 419) = 0.94

Maximum PHF is 0.94 at 4PM with flow rate of 2363 PCU/hr

Annual Average Daily Traffic = Flow rate x HEF x WEF x MEF

= 2363×14.6157×0.984×1.034 (4pm, Wed, Feb)

= 35140 PCU/ Day

4.1.5 Analysis for Traffic Volume on Bondar to Naiorpul Road

On 24th February 2025, collected data for three different hours: 9:00 AM, 1:00 PM, and 4:00 PM.

Table 13: Traffic Data for 9:00 AM Bondar to Naiorpul Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Numbe	982	372	125	5	7
PCE	0.75	0.5	1	3	3
PCU	736	186	125	15	21

So, Flow rate = 736 + 186 + 125 + 15 + 21 = 1083 PCU/hr

Therefore, Peak Hour factor was (PHF) = 1083 / (6 × 217) = 0.831

Table 14: Traffic Data for 1:00 PM Bondar to Naiorpul Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1398	698	143	4	19
PCE	0.75	0.5	1	3	3
PCU	1048	349	143	12	57

So, Flow rate = 1048 + 349 + 143 + 12 + 57 = 1609 PCU/hr

Therefore, Peak Hour factor (PHF) = 1609 / (6 × 298) = 0.898

Table 15: Traffic Data for 4:00 PM Bondar to Naiorpul Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1690	769	142	2	16
PCE	0.75	0.5	1	3	3
PCU	1267	384	142	6	48

So, Flow rate = 1267 + 384 + 142 + 6 + 48 = 1847 PCU/hr

Therefore, Peak Hour factor (PHF) = 1847 / (6 × 333) = 0.924

Maximum PHF is 0.924 at 4PM with flow rate of 1847 PCU/hr

Annual Average Daily Traffic = Flow rate x HEF x WEF x MEF

= 1847×14.6157×0.958×1.034 (4pm, Mon, Feb)

= 26741 PCU/ Day

4.1.6 Analysis for Traffic Volume on Upashahar to Naiorpul Road

On 24th February 2025, collected data for three different hours: 9:00 AM, 1:00 PM, and 4:00 PM.

Table 16: Traffic Data for 9:00 AM Upashahar to Naiorpul Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	569	243	209	29	31
PCE	0.75	0.5	1	3	3
PCU	427	121	209	87	93

So, Flow rate = 427 + 121 + 209 + 87 + 93 = 937 PCU/hr

Therefore, Peak Hour factor (PHF) = 937 / (6 × 178) = 0.876

Table 17: Traffic Data for 1:00 PM Upashahar to Naiorpul Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	1008	660	398	45	38
PCE	0.75	0.5	1	3	3
PCU	756	330	398	135	114

So, Flow rate = 756 + 330 + 398 + 135 + 114 = 1733 PCU/hr

Therefore, Peak Hour factor (PHF) = 1733 / (6 × 320) = 0.902

Table 18: Traffic Data for 4:00 PM Upashahar to Naiorpul Road

Vehicle Types	CNG	Bike	Car	Bus	Truck
Vehicle Number	973	668	493	41	35
PCE	0.75	0.5	1	3	3
PCU	730	668	493	123	105

So, Flow rate = 730 + 334 + 493 + 123 + 105 = 1785 PCU/hr

Therefore, Peak Hour factor (PHF) = 1785 / (6 × 313) = 0.95

Maximum PHF is 0.95 at 4PM with flow rate of 1785 PCU/hr

Annual Average Daily Traffic = Flow rate x HEF x WEF x MEF

= 1785×14.6157×0.995×1.034 (4pm, Sun, Feb)

= 26841 PCU/ Day

4.2 Vehicle Kilometer Travel (VKT) Calculation

4.2.1 Actual Vehicle Number of Each Type

4.2.1.1 On Modina-Market to Subid-Bazar Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 36048 PCU/day

Table 19: Vehicle Number on Modina-Market to Subid-Bazar Road

Vehicle Types	Composition(%)	AADT x Percent	PCE	Actual Number
CNG	61.72	22248.8	0.75	29665
Bike	14.66	5284.6	0.5	10569
Car	14.84	5349.5	1	5349
Bus	4.6	1658.2	3	552
Truck	4.18	1506.8	3	502

4.2.1.2 On Tilagor to Majortila Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 26168 PCU/day

Table 20: Vehicle Number on Tilagor to Majortila Road

Vehicle Types	Composition(%)	AADT x Percent	PCE	Actual Number
CNG	51.62	13507.9	0.75	18010
Bike	18.79	4916.9	0.5	9833
Car	12.57	3289.3	1	3289
Bus	8.76	2292.3	3	764
Truck	8.26	2161.5	3	720

4.2.1.3 On Naiorpul to Tilagor Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 18678 PCU/day

Table 21: Vehicle Number on Naiorpul to Tilagor Road

Vehicle Types	Composition(%)	AADT x Percent	PCE	Actual Number
CNG	54.78	10231.8	0.75	13642
Bike	18.15	3390	0.5	6780
Car	12.98	2424.4	1	2424
Bus	8.6	1606.3	3	535
Truck	5.49	1025.4	3	341

4.2.1.4 On Upashahar to Humayun-Chattar Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 35140 PCU/day

Table 22: Vehicle Number on Upashahar to Humayun-Chattar Road

Vehicle Types	Composition(%)	AADT x Percent	PCE	Actual Number
CNG	51.2	17991.6	0.75	23988
Bike	16.72	5875.4	0.5	11750
Car	17.73	6230.3	1	6230
Bus	5.21	1830.7	3	610
Truck	9.14	3211.7	3	1070

4.2.1.5 On Upashahar to Naiorpul Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 26841 PCU/day

Table 23: Vehicle Number on Upashahar to Naiorpul Road

Vehicle Types	Composition(%)	AADT x Percent	PCE	Actual Number
CNG	40.9	10977.9	0.75	14637
Bike	18.71	5021.9	0.5	10043
Car	27.62	7413.4	1	7413
Bus	6.89	1849.3	3	616
Truck	5.88	1578.2	3	526

4.2.1.6 On Bondar to Naiorpul Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 26741 PCU/day

Table 24: Vehicle Number on Bondar to Naiorpul Road

Vehicle Types	Composition(%)	AADT x Percent	PCE	Actual Number
CNG	68.6	18344.3	0.75	24459
Bike	20.79	5559.45	0.5	11118
Car	7.69	2056.3	1	2056
Bus	0.32	85.5	3	28
Truck	2.6	695.2	3	231

4.2.1.7 On Kamran-Chattar to Bondar Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 20885 PCU/day

Table 25: Vehicle Number on Kamran-Chattar to Bondar Road

Vehicle Types	PCU	Composition (%)	AADT x Percent	PCE	Actual Number
CNG	611	44.66	9327	0.75	12436
Bike	162	11.85	2474	0.5	4949
Car	108	7.89	1647	1	1647
Rickshaw	430	31.43	6564	2	3282
Bus	21	1.54	321	3	107
Truck	36	2.63	549	3	183

(Emon et al, 2024)

4.2.1.8 On Chowhatta to Bondar Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 30228 PCU/day

Table 26: Vehicle Number on Chowhatta to Bondar Road

Vehicle Types	PCU	Composition (%)	AADT x Percent	PCE	Actual Number
CNG	666	33.64	10168	0.75	13558
Bike	283	14.29	4319	0.5	8639
Car	168	8.48	2563	1	2563
Rickshaw	836	42.22	12762	2	6381
Bus	15	0.76	184	3	76
Truck	12	0.61	229	3	61

(Emon et al., 2024)

4.2.1.9 On Chowhatta to Ambarkhana Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 39174 PCU/day

Table 27: Vehicle Number on Chowhatta to Ambarkhana Road

Vehicle Types	PCU	Composition (%)	AADT x Percent	PCE	Actual Number
CNG	828	32.27	12641	0.75	16855
Bike	315	12.28	4810	0.5	9621
Car	150	5.85	2291	1	2291
Rickshaw	1252	48.79	19112	2	9556
Bus	6	0.23	90	3	30
Truck	15	0.58	227	3	75

(Emon et al, 2024)

4.2.1.10 On Subid-Bazar to Ambarkhana Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 38212 PCU/day

Table 28: Vehicle Number on Subid-Bazar to Ambarkhana Road

Vehicle Types	PCU	Composition (%)	AADT x Percent	PCE	Actual Number
CNG	851	34	12992	0.75	17322
Bike	245	9.79	3740	0.5	7481
Car	175	6.99	2671	1	2671
Rickshaw	1202	48.02	18349	2	9174
Bus	21	0.84	320	3	107
Truck	9	0.36	137	3	45

(Emon et al, 2024)

4.2.1.11 On Airport-Road to Ambarkhana Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 34090 PCU/day

Table 29: Vehicle Number on Airport-Road to Ambarkhana Road

Vehicle Types	PCU	Composition (%)	AADT x Percent	PCE	Actual Number
CNG	610	27	9313	0.75	12417
Bike	302	13.52	4608	0.5	9217
Car	227	10.17	3466	1	3466
Rickshaw	1040]	46.57	15875	2	7937
Bus	15	0.67	228	3	76
Truck	39	1.75	596	3	198

(Emon et al, 2024)

4.2.1.12 On Tilagor to Ambarkhana Road

After converting 4PM data to PCU value, the percentage of vehicle composition was determined.

AADT = 33845 PCU/day

Table 30: Vehicle Number on Tilagor to Ambarkhana Road

Vehicle Types	PCU	Composition (%)	AADT x Percent	PCE	Actual Number
CNG	733	33.05	11185	0.75	14914
Bike	185	8.34	2822	0.5	5645
Car	119	5.36	1814	1	1814
Rickshaw	1124	50.68	17152	2	8576
Bus	24	1.08	365	3	121
Truck	33	1.49	504	3	168

(Emon et al, 2024)

4.2.2 VKT of Each Road

4.2.2.1 On Modina-Market to Subid-Bazar Road

Trip Distance = 1.2 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 31: VKT for Modina-Market to Subid-Bazar Road

Vehicle Types	Actual Number	VKT (km)
CNG	29665	35598
Bike	10569	12682.8
Car	5349	6418.8
Bus	552	662.4
Truck	502	602.4

4.2.2.2 On Naiorpul to Tilagor Road

Trip Distance = 2.5 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 32: VKT for Naiorpul to Tilagor Road

Vehicle Types	Actual Number	VKT (km)
CNG	13642	34106
Bike	6780	16950.2
Car	2424	6061
Bus	535	1338.5
Truck	341	854.5

4.2.2.3 On Tilagor to Majortila Road

Trip Distance = 1.2 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 33: VKT for Tilagor to Majortila Road

Vehicle Types	Actual Number	VKT (km)
CNG	18010	21612.6
Bike	9833	11800.7
Car	3289	3947.1
Bus	764	916.9
Truck	720	864.6

4.2.2.4 On Upashahar to Humayun-Chattar Road

Trip Distance = 1.1 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 34: VKT for Humayun-Chattar Road

Vehicle Types	Actual Number	VKT (km)
CNG	23988	26387.7
Bike	11750	12925.8
Car	6230	6853.3
Bus	610	671.2
Truck	1070	1177.6

4.2.2.5 On Upashahar to Naiorpul Road

Trip Distance = 1.1 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 35: VKT for Upashahar to Naiorpul Road

Vehicle Types	Actual Number	VKT (km)
CNG	14637	16101
Bike	10043	11048.2
Car	7413	8154.8
Bus	616	678
Truck	526	717.2

4.2.2.6 On Bondar to Naiorpul Road

Trip Distance = 0.5 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 36: VKT for Bondar to Naiorpul Road

Vehicle Types	Actual Number	VKT (km)
CNG	24459	12229.5
Bike	11118	5559.4
Car	2056	1028.2
Bus	28	14.2
Truck	231	115.8

4.2.2.7 On Kamran-Chattar to Bondar Road

Trip Distance = 0.8 km (from Taltola to Bondar)

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 37: VKT for Kamran-Chattar to Bondar Road

Vehicle Types	Actual Number	VKT (km)
CNG	12436	9948.8
Bike	4949	3959.2
Car	1647	1317.6
Bus	107	85.6
Truck	183	146.4

4.2.2.8 On Chowhatta to Bondar Road

Trip Distance = 0.85 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 38: VKT for Chowhatta to Bondar Road

Vehicle Types	Actual Number	VKT (km)
CNG	13558	11524.3
Bike	8639	7343.2
Car	2563	2178.6
Bus	76	64.6
Truck	61	51.9

4.2.2.9 On Chowhatta to Ambarkhana Road

Trip Distance = 0.7 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 39: VKT for Chowhatta to Ambarkhana Road

Vehicle Types	Actual Number	VKT (km)
CNG	16855	11798.5
Bike	9621	8177.9
Car	2291	1603.7
Bus	30	21
Truck	75	52.5

4.2.2.10 On Subid-Bazar to Ambarkhana Road

Trip Distance = 3 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 40: VKT for Subid-Bazar to Ambarkhana Road

Vehicle Types	Actual Number	VKT (km)
CNG	17322	51966
Bike	7481	22443
Car	2671	8013
Bus	107	321
Truck	45	129

4.2.2.11 On Airport-Road to Ambarkhana Road

Trip Distance = 3.9 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 41: VKT for Airport-Road to Ambarkhana Road

Vehicle Types	Actual Number	VKT (km)
CNG	12417	48426.3
Bike	9217	35946.3
Car	3466	13517.4
Bus	76	296.4
Truck	198	772.2

4.2.2.12 On Tilagor to Ambarkhana Road

Trip Distance = 4 km

VKT = AADT × Road Length

= Number of Vehicle x Trip Distance

Table 42: VKT for Tilagor to Ambarkhana Road

Vehicle Types	Actual Number	VKT (km)
CNG	14914	59668
Bike	5645	22580
Car	1814	7256
Bus	121	484
Truck	168	672

4.2.3 VKT for Each Vehicle Type

Summed up all the VKT of each vehicle at each Road section.

Total VKT of CNG = (35598 + 34106 + 21612.6 + 26387.7 + 16101 + 12229.5 + 9948.8 + 11524.3 + 11798.5 + 51966 + 48426.3 + 59668) km

= 339366.7 km a Day

Total VKT of Bike = (12682.8 + 16950.2 + 11800.7 + 12925.8 + 11048.2 + 5559.4 + 3959.2 + 7343.2 + 8177.9 + 22443 + 35946.3 + 22580) km

= 171416.7 km a Day

Total VKT of Car = (6418.8 + 6061 + 3947.1 + 6853.3 + 8154.8 + 1028.2 + 1317.6 + 2178.6 + 1603.7 + 8013 + 13517.4 + 7256) km

= 66349.5 km a Day

Total VKT of Bus = (662.4 + 1338.5 + 916.9 + 671.2 + 678 + 14.2 + 85.6 + 64.6 + 21 + 321 + 296.4 + 484) km

= 5553.8 km a Day

Total VKT of Truck = (602.4 + 854.5 + 864.6 + 1177.6 + 717.2 + 115.8 + 146.4 + 51.9 + 52.5 + 129 + 772.2 + 672) km

= 6156.1 km a Day

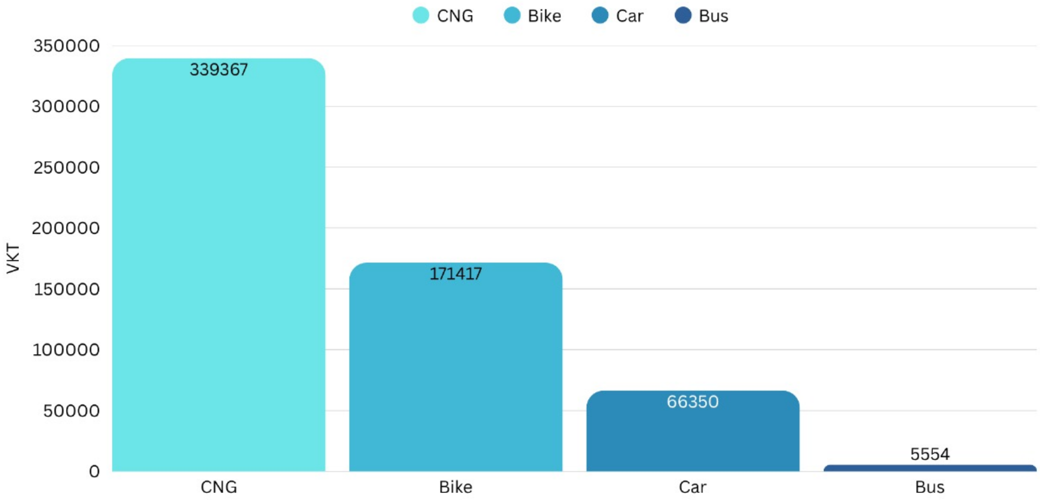

Figure 2: VKT per Day of CNG, Bike, Car, Bus

4.3 Emission Calculation

4.3.1 For ICEV

4.3.1.1 Emission from CNG Auto-Rickshaws

The VKT of the CNG auto-rickshaw is 339366.7 km a day.

EF = 2.1 kg per kg of CNG (Table C2)

Mileage avg = 31 km per kg (Table B2)

Emission = 339366.7×2.1 / 31 = 22989.3 kg of eCo2

4.3.1.2 Emission from Bikes

The VKT of the bike is 171416.7 km a day.

EF = 2.8 kg per liter of Petrol (Table C2)

Mileage avg = 45 km per liter (Table B1)

Emission = 339366.7×2.8 / 45 = 10665.9 kg of eCo2

4.3.1.3 Emission from Cars

The VKT of the car is 66349.5 km a day. The exact data on different fuel usages per kilometer for cars was unavailable. A representative of a petrol pump said that approximately 80% of cars use CNG as fuel. Therefore, different compositions were prepared.

1. If 80% CNG + 20% Gasoline, $(2.1 \times 0.8) + (2.8 \times 0.2)$. So the emission factor is 2.24.

2. If 70% CNG + 30% Gasoline, $(2.1 \times 0.7) + (2.8 \times 0.3)$. So the emission factor is 2.31.

3. If 60% CNG + 40% Gasoline, $(2.1 \times 0.6) + (2.8 \times 0.4)$. So the emission factor is 2.38.

4. If 50% CNG + 50% Gasoline, $(2.1 \times 0.5) + (2.8 \times 0.5)$. So the emission factor is 2.45.

If the 80-20 ratio was considered, would obtain the least amount of emission reduction after converting to E-car. But considering–50-50 will show more emission reduction. To observe the differences in emissions at each ratio, Table-42 is presented.

Here, the average mileage is 14 km/l or 14 km/kg (Table B4).

Table 43: Car Emission at Different fuel Composition

Fuel Composition	Emission (kg)
80, 20	10615.9
70,30	10947.6
60, 40	11279.4
50, 50	11611.2

4.3.1.4 Emission from Buses

The VKT of the bus is 5553.8 km a day.

EF = 3.2 kg per Liter of Diesel (Table C2)

Mileage avarage = 4 km per liter (Table B3)

Emission = 5553.5 × 2.8 / 4 = 4443 kg of eCo2

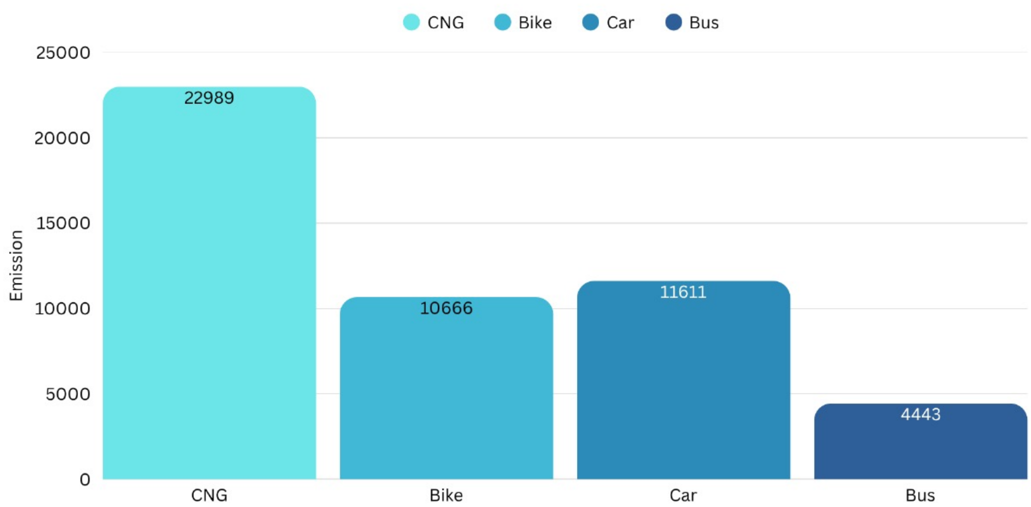

Figure 3: Emission per Day from ICEVs

4.3.2 For EV

To convert to electric vehicles, vehicle activity is considered rather than the number of vehicles. For example, if all the existing vehicles are to be converted to electric vehicles, the previously calculated 100% Vehicle Kilometers Traveled (VKT) of ICEVs is considered as the VKT of EVs. To calculate the activity of the emissions from EVs, we need to consider the electricity required and the much CO_2 equivalent produced from the grid power of Bangladesh.

Currently, 100% conversion to electric power is not possible and is also not realistic. The Bangladeshi government has set a goal to penetrate 30% of EV in the Bangladesh-vehicle-market by 2030 (Ministry of Road Transport and Bridges, 2023). Therefore, in our calculation, 30% electrification is considered, which translates to 30% of the previously calculated VKT. This represents a realistic and actionable benchmark.

4.3.2.1 Emission From Electric Auto-Rickshaw at Various Conversion

Based on the collected data (Table B5), an average mileage of 20 km/kWh for electric auto-rickshaws was assumed. The current Vehicle Kilometers Traveled (VKT) by CNG auto-rickshaws in Sylhet is 339,366.7 km per day.

The Table-44 presents the estimated VKT for the conversion scenario, along with the required electricity and resulting emissions (in kg CO_2 equivalent). The emissions were calculated based on the electricity demand corresponding to each VKT level.

EF(grid) = 0.4932 kg of eCO2 per kWh (**Appendix C**)

$VKT_{(100\%)}$ = 339,366.7 km per day at 100%

$VKT_{(30\%)}$ = (339,366.7×30%) = 101810.01 km per day at 30%

Table 44: Electric Auto-Rickshaw Emission at Different Conversion

Conversion (%)	VKT(km)	Electricity Req (kWh)	Emission (kg eCO_2)
100	339366.7	16968.33	8368.78
30	101810.01	5090.50	2510.63

4.3.2.2 Emission From Electric Bike

From the collected data (Table B6), mileage 40 km per kWh.

The VKT of the Bike is 171416.7 km a day.

$VKT_{(100\%)}$= 171416.7 km per day at 100%

$VKT_{(30\%)}$ = (171416.7×30%) = 51425.01 km per day at 30%

EF(grid) = 0.4932 kg of eCO2 per kWh (**Appendix C**)

Table 45: Electric-Bike Emission at Different Conversion

Conversion (%)	VKT(km)	Electricity Req (kWh)	Emission (kg eCO_2)
100	171416.7	4285.41	2113.56
30	51425.01	1285.62	634.07

4.3.2.3 Emission From Electric Car

From the collected data (Table B7), mileage 8 km per kWh.

The VKT of the car is 66349.5 km a day

$VKT_{(100\%)}$ = 66349.5 km per day at 100%

$VKT_{(30\%)}$ = (66349.5×30%) = 19904.85 km per day at 30%

EF(grid) = 0.4932 kg of eCO2 per kWh (**Appendix C**)

Table 46: Electric-Car Emission at Different Conversion

Conversion (%)	VKT	Electricity Req (kWh)	Emission (kg eCO_2)
100	66349.5	8293.68	4090.44
30	19904.85	2488.10	1227.13

4.3.2.4 Emission From Electric Bus

From the collected data (Table B8), mileage 1 km per kWh.

The VKT of the bus is 5553.8 km a day.

$VKT_{(100\%)}$ = 5553.8 km per day at 100%

$VKT_{(30\%)}$ = (5553.8×30%) = 1666.14 km per day at 30%

EF(grid) = 0.4932 kg of eCO2 per kWh (**Appendix C**)

Table 47:Electric-Bus at Different Conversion

Conversion (%)	VKT (km)	Electricity Req (kWh)	Emission (kg eCO_2)
100	5553.8	5553.8	2739.13
30	1666.14	1666.14	821.74

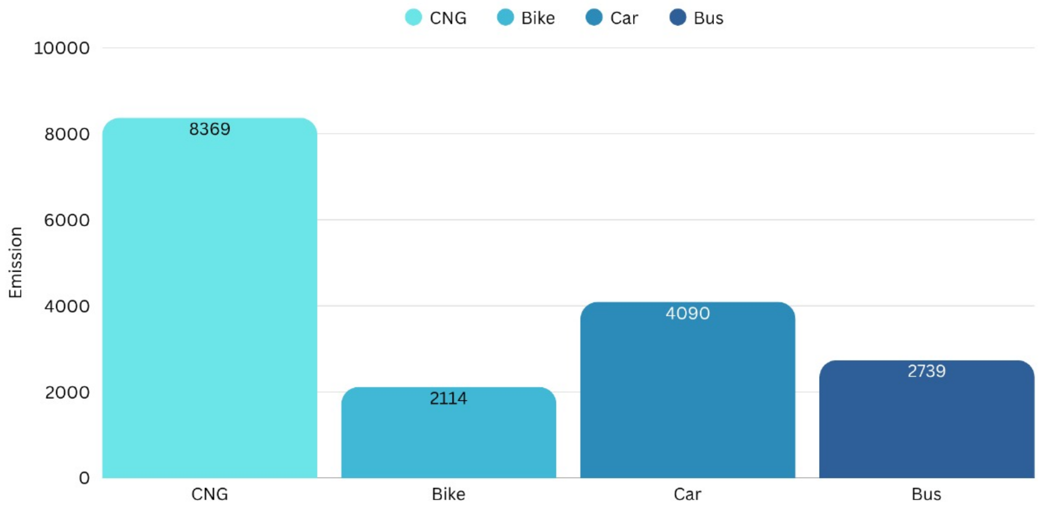

Figure 4: EV Emission per Day at 100% Conversion

4.4 Emission Reduction

4.4.1 Emission Reduction After Converting to CNG Auto-Rickshaw

ICEV emission are 22989.3 kg of eCO_2 (mileage 31 km/kg).

Table 48: Emission Reduction by CNG-Auto

Conversion (%)	EV Emission (kg eCO_2)	Total Daily Emission (kg eCO_2)	Emission Reduction (%)
0%	0	22989.3	0
30%	2510.63	18603.14	19.1
100%	8368.78	8368.78	63.6

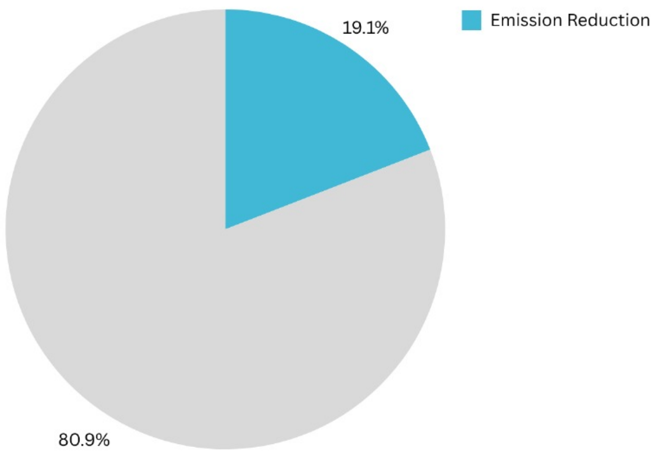

Figure 5: eCo2 Reduce by Electric-Auto Rickshaw

4.4.2 Emission Reduction: Bike

ICEV emission are 10665.9 kg of eCO_2 (mileage = 45 km/l)

Table 49: Emission Reduction by Bike

Conversion %	EV Emission (kg eCO_2)	Total Daily Emission (kg eCO_2)	Emission Reduction %
0%	0	10665.9	0
30%	634.07	8100.2	24.05
100%	2113.56	2113.56	80.18

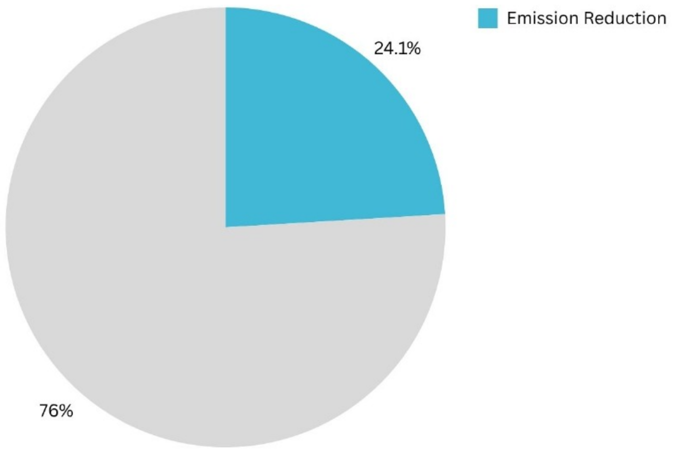

Figure 6: eCo2 Reduce by Electric-Bike

4.4.3 Emission Reduction: Car

ICEV emissions are 11611.2 kg of eCO_2.(14 km/l with 50 and 50 compositions). For the 80-20 composition, the minimum reduction was 11.87%. Also found that, if considered the 50-50 composition reduction was 19.43%, shown in Table-50.

Table 50: Emission Reduction by Car

Conversion %	EV Emission (kg eCO_2)	Total Daily Emission (kg eCO_2)	Emission Reduction %
0%	0	11611.2	0
30%	1227.13	9354.97	19.43
100%	4090.44	4090.44	64.77

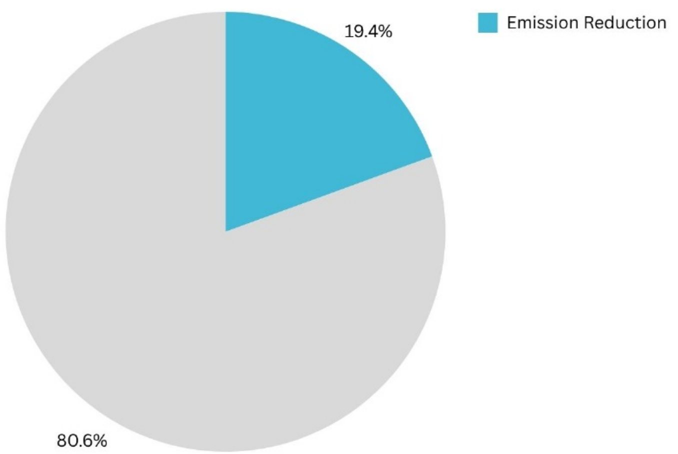

Figure 7: eCo2 Reduce by Electric-Car

4.4.4 Emission Reduction: Bus

ICEV emission is considered 4433.8 kg of eCO_2 (mileage = 4 km/l).

Table 51: Emission Reduction by Bus

Conversion (%)	EV Emission (kg eCO_2)	Total Daily Emission (kg eCO_2)	Emission Reduction (%)
0%	0	4433.8	0
30%	821.74	3925.4	11.46
100%	2739.13	2739.13	38.22

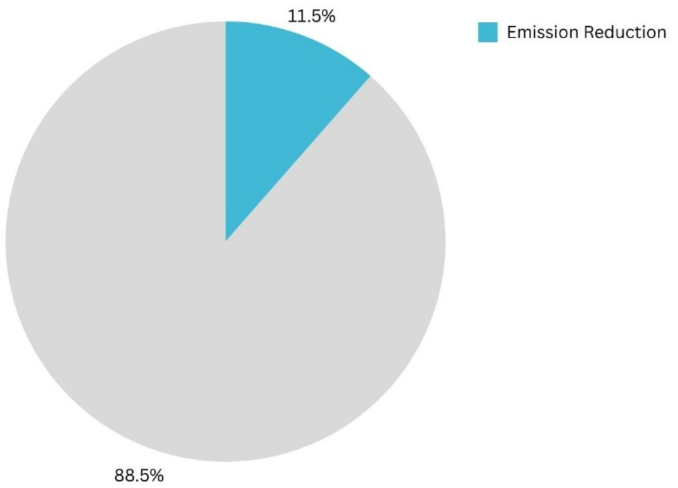

Figure 8: eCo2 Reduce by Electric Bus

4.4.5 Emission Reduction : All type

The total eCO_2 reduction after converting all types of vehicles (CNG auto-rickshaw, Bike, Car, and Bus) at different conversion rates is shown.

Total daily emission from ICEV

$$= 22989.3 + 10665.9 + 11611.2 + 4433.8 = 49700 \text{ kg } eCO_2$$

Total daily emission from EV

$$= 8368.78 + 2113.56 + 4090.44 + 2739.13 = 17311.9 \text{ kg } eCO_2$$

Total daily emissions from EV after 30% conversion

$$= 18603.14 + 8100.2 + 9354.97 + 3925.4 = 39983.7 \text{ kg } eCO_2.$$

Table 52: Emission Reduction All Type

Conversion (%)	Total Emission (kg of eCO_2)	Reduction rate (%)
0	49700	0
30	39983.7	19.54
100	17311.9	65.167

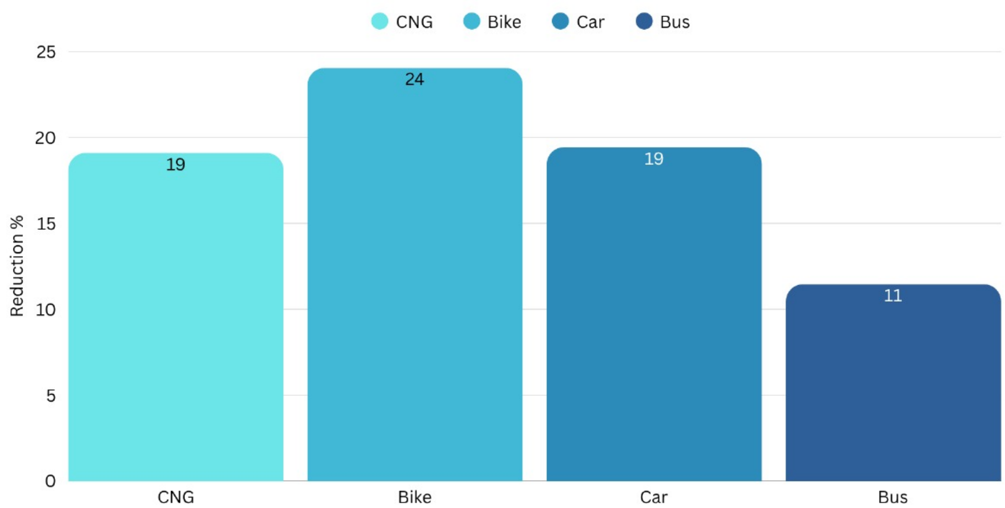

Figure 9: eCO2 Reduction at 30% Conversion by Each Vehicle Vype

Chapter 5

CONCLUSION AND RECOMMENDATION

5.1 General

The findings of this thesis in the last chapter is concluded. Practical recommendations, limitations of this study, and further research scope are provided in this section. Hope it reduces transport-related CO_2 emissions through the adoption of electric vehicles (EVs) in Sylhet City, even if it is a small percentage. As previously mentioned, this research focused on quantifying emissions from selected internal combustion engine vehicles (ICEVs) and then compared them with electric vehicle (EVs) emissions under different adoption scenarios. In this analysis, traffic volume data, vehicle type-specific mileage, and emission factors of different fuels, with grid carbon intensity relevant to Bangladesh were included. Thus, this study provides a realistic and data-driven assessment of the possible environmental benefits of EV transition in an urban context.

Thus, four main sections of this paper are presented. The Conclusion summarizes the key findings and implications of this research. The recommendations summarize policy measures to support sustainable mobility. Limitations section tells the data gaps of the study, lastly in further research and data collection section is discussion about future research.

5.2 Conclusion

This study aims to determine the potential for reducing carbon dioxide (CO_2) emissions in Sylhet City through the gradual adoption of electric vehicles (EVs). Vehicle-count data from 12 key road segments and Vehicle Kilometers Traveled (VKT) were estimated for four major vehicle types (buses, cars, motorcycles, and CNG auto-rickshaws). Carbon dioxide emissions were then calculated separately for internal combustion engine vehicles (ICEVs) and their electric alternatives using standardized emission factors for fuel and grid-carbon-intensity values.

The baseline result was that the selected ICEVs emitted approximately 49 tonnes of CO_2-equivalent per day. Among these vehicles, CNG auto-rickshaws are the largest contributor, followed by cars and motorcycles, which reflects their relative fleet sizes and continuous urban operation. In contrast, after a hypothetical 100 %

conversion to EVs powered by Bangladesh's current grid electricity mix (different sources), emissions were substantially lower.

Two EV-penetration scenarios were modeled: 30 % and 100 % conversion of ICEVs to EVs. Under the 30 % scenario, daily CO_2 emissions fall to 39.9 tonnes from 49 tonnes, a 19 % reduction, which indicates that even a small electrification of 30% can yield significant climate benefits, even though the grid is not yet fully renewable. Notably, electric motorcycles achieved the greatest individual reduction of 24 % with CNG auto-rickshaws (19%) and cars(19.4%), which also contributed substantially to the overall savings. It is clear from the results and discussion that electrizing cars and CNG automobiles might be a sustainable and appropriate solution for SDG strategies in Bangladesh.

Ultimately, electrifying common vehicles such as CNG auto-rickshaws, cars, and motorcycles can deliver significant carbon footprint reductions for Sylhet.. However, the magnitude of these benefits is closely linked to the cleanliness (Renewable) of the power grid. Overall, Sylhet offers a wonderful case for the implementation of urban EV. These data-driven insights can provide a robust foundation for policymakers seeking to decarbonize a city's transport sector and improve overall air quality.

5.3 Recommendations

1. High-emission vehicle categories such as CNG auto-rickshaws and motorcycles should be prioritized for electrification.
2. Financial incentives such as taxes, registration fees, and subsidies should be lowered for EVs.
3. Charging Stations need to be developed.
4. The integration of solar-based EV charging stations in Sylhet can serve as a pilot initiative.
5. Promote Local EV Manufacturing.
6. Educate the public on the economic and environmental advantages of EVs.

5.4 Limitations

1. Limited fuel types, such as LPG, Octane, Diesel for cars, were not considered.
2. Data Gaps in Bi-Fuel Usage for cars.
3. The analysis excludes trucks, lagunas, and vans.
4. Electricity loss was not considered.
5. Emissions are calculated based only on operational emissions, excluding manufacturing, disposal.
6. Lack of public review on fuel efficiency of electric vehicles.

5.5 Further Research and Data Collection

1. Future studies should incorporate more vehicle types, such as trucks, lagunas, and vans, and extend the coverage to all road segments for a comprehensive emissions analysis.
2. Bangladesh-specific emission factors should be developed through field testing and empirical research.
3. Future research should include life cycle assessments (LCA) to account for battery production, disposal, and the full upstream impact of EV technology.
4. The average vehicle travel or local expansion factors (for AADT) must be developed.

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APPENDIX A

Traffic Survey Data

Table A1: Tilagor to Majortila 2/18/25

Time	CNG	Bike	Car	Bus	Truck
4.00-4.10pm	196	130	39	8	6
4.10-4.20pm	206	113	28	8	8
4.20-4.30pm	207	114	40	9	9
4.30-4.40pm	188	116	36	7	6
4.40-4.50pm	210	111	46	10	7
4.50-5.00pm	243	99	39	11	14

Table A2: Modina-Market to Subid-Bazar 2/27/25

Time	CNG	Bike	Car	Bus	Truck
4.00-4.10pm	355	119	72	11	9
4.10-4.20pm	338	109	57	6	7
4.20-4.30pm	318	114	48	4	6
4.30-4.40pm	332	121	77	5	4
4.40-4.50pm	309	143	56	3	4
4.50-5.00pm	382	121	58	9	5

Table A3: Naiorpul to Tilagor 2/26/25

Time	CNG	Bike	Car	Bus	Truck
4.00-4.10pm	161	88	24	7	2
4.10-4.20pm	155	76	28	5	6
4.20-4.30pm	192	65	31	6	5
4.30-4.40pm	127	84	31	6	4
4.40-4.50pm	155	74	22	5	2
4.50-5.00pm	128	69	27	7	4

Table A4: Upashahar(Rose-View) to Naiorpul 2/23/25

TIME	CNG	Bike	Car	Bus	Truck
4.00-4.10pm	164	113	90	3	6
4.10-4.20pm	164	100	83	7	12
4.20-4.30pm	170	130	77	7	2
4.30-4.40pm	160	99	69	8	6
4.40-4.50pm	163	122	90	6	3
4.50-5.00pm	152	104	84	10	6

Table A 5: Bondar to Naiorpul 2/24/25

Time	Cng	Bike	Car	Bus	Truck
4.00-4.10pm	291	135	23	0	1
4.10-4.20pm	307	123	23	0	4
4.20-4.30pm	287	117	26	1	3
4.30-4.40pm	240	120	22	0	3
4.40-4.50pm	278	113	25	0	1
4.50-5.00pm	287	161	23	1	4

Table A6: Upashahar(ROSE-View) to Humayun-Chattar 02/19/25

Time	CNG	Bike	Car	Bus	Truck
4.00-4.10pm	270	161	77	6	7
4.10-4.20pm	299	106	91	4	13
4.20-4.30pm	280	120	69	8	13
4.30-4.40pm	264	126	63	7	21
4.40-4.50pm	236	110	63	8	6
4.50-5.00pm	265	168	56	8	12

Table A7: AADT Data from 2024 Study

Intersection	AADT (PCU/day)
Kamran-Chattar to Bondar	20885
Chowhatta to Bondar	30228
Chowhatta to Ambarkhana	39174
Subid-Bazar to Ambarkhana	38212
Airport-Road to Ambarkhana	34090
Tilagor to Ambarkhana	33845

(Emon et al, 2024)

APPENDIX B

ICEV and EV Data

Table B1: Bike Mileage Data

Vehicle	Mileage (km/L)	Vehicle	Mileage (km/L)
Suzuki Gixxer F1 150	40	TVS wego 110	42
Honda x-blade 160	45	Runner Skooty 110	37
Yamaha R15M	42	Hero Maestro edge 110cc	37
Suzuki gsx-R150	35	Yamaha Aerox 155	38
Yamaha fzs v2	40	Vespa VXL 125	38
Yamaha FZS V3 abs	45	Runner Bolt 165R	38
Bajaj discover 125	48	Runner Knight Rider 150	43
Hero xtreme 125R	58	Runner Turbo 125	40
TVS metro plus	55	Runner Royal Plus 110cc	45
Yamaha YZF-R15 (V4.0)	44	Runner Bullet 100	45
Honda CBR 150R	39	Runner AD 80S Deluxe	51
Suzuki gsx-R600	18	Vespa VXL 150	45
TVS xl 100	58	Vespa SXL 125	35
TVS stryker 125	69	Vespa SXL 150	34
TVS Ntorq 125(scooter)	37	Vespa Elegante VXL 150	45
TVS apache 160 4v	37	Vespa LX 125	32
TVS raider 125	50	Apache RTR 160 4V	45
Honda Dio 110cc Scooter	40	Suzuki Hayate EP	55
Hero Glamour	65	Yamaha ray zr 125	38

Table B2: CNG Auto-Rickshaw Mileage Data

Vehicle	Mileage (km/kg)	Vehicle	Mileage (km/kg)
Bajaj Re CNG	27	Piaggio Ape Xtra	35
Person 1	34	Person 4	25
Person 2	30	Person 5	41
Person 3	29	Person 6	36
TVS king deluxe	40	Person 7	32

Table B3: BUS Mileage Data

Vehicle	Mileage (km/L)	Vehicle	Mileage (km/L)
Tata LP 407	3 km/L	Person 1	3 km/L
Tata Ultra	5 km/L	Eicher Starline	3 to 4 km/L
Hino AK	4 km/L	Person 2	4 km/L

Table B4: Car Mileage Data

Vehicle	Mileage (km/L)	Vehicle	Mileage (km/L)
Toyota Noah hybrid	22	Toyota esquire hybrid	12
Toyota LiteAce	9	Toyota Noah DX(hybrid)	17
Toyota TownAce Gl	8	Toyota Noah x	14
Kia Seltos	17	Toyota Corolla dx Wagon	11
Toyota Corolla Xe Saloon	10	Suzuki Wagon R	21
Toyota Probox Dx/Gl	9	Toyota corolla SE limited	14
Toyota rav 4	12	Nissan X trail	14
Mitsubishi I200 sportero	12	Nissan X trail hybrid	8
Toyota allion a15	10	Toyota Noah kr42 Gl super	11
Toyota C Hr	15	Toyota Hiace super gl	13
Toyota Noah G	11	Toyota Corolla altis	21
Toyota Prius (HYBRID)	17	Toyota Corolla X	11
Toyota Sprinter	12	Toyota Corolla G	14
Toyota Premio	14	Toyota Voxy	10
Toyota Harrier	10	Toyota C HR (Hybrid)	25
Toyota Corolla Axio	12	Toyota 110	11
Toyota Corolla Fielder	12	Toyota Noah	9

Table B5: Electric Auto-Rickshaw Mileage

Vehicle	Mileage (km/kWh)
TVS King EV max	19.45
Greaves Eltra city	20.83
Bajaj Re E tec 9.0	20
Montra Electric super auto	19.84
Piaggio Ape E City FX max	18.75
Mahindra Treo electric auto rickshaw	17.63
5 seater EverBright	20.83
Palki Cityboy v3	24

Table B6: Electric Bike Mileage

Vehicle	Mileage (km/kWh)
Revoo A01	59
Revoo C03	47.6
Infinity Revolt RV400	46
AIMA F626	50.5
Revoo C00	53.4
Revoo A01	59
Runner eWave Eco	34.7
Yadea M6	32
Energica Ego	35.8
Yadea T5	42.7
Yadea Keenless	28

Table B7: Electric Car Mileage

Vehicle	Mileage (km/kWh)
BYD Atto 3	6.94
MG ZS EV	9
Nissan Leaf	6
Haval GWM Ora EV	7.93
MG 4 EV	6.7

Table B8: Electric Bus Mileage

Vehicle	Mileage (km/kWh)
BYD K7M	1.34
BYD K8M	0.81
BYD K9M	1.15

APPENDIX C

Emission Factor

Table C1: Grid Emission Factors of Power Source in Bangladesh

Generation Source	Emission (gCO_2 eq / kWh)
Coal	910
Gas	410
Oil	374
Renewable energy (Solar) (infrastructure and supply chain)	48

(Schlömer et al, 2014)

C.1 Emission Factor (Grid) Calculation

Bangladesh grid power is generated using 44.35% gas, 26.18% coal, 20.57% oil, and 3.62% renewable sources. (BPDB, 2025)

Mix emission factor = 0.4435×410 + 0.2618×910 + 0.2057×347 + 0.0362×48

= 493.2 gm/kWh

Table C2: Emission Factor of Different Fuels

Fuel	Emission Factor
Diesel	3.2 kg CO_2 eq per litre
Gasoline	2.8 kg CO_2 eq per litre
CNG	2.1 kg CO_2 eq per kg

(Schlömer et al, 2014)

APPENDIX D

Road Length

Table D1: Each Section Length

Road Section	Distance
Bondar to Naiorpul	0.5 km
Naiorpul to Tilagor	2.5 km
Tilagor to Majortila	1.2 km
Kamran-Chattar to Bondar	0.8 km
Bondar to Chowhatta	0.85 km
Chowhatta to Ambarkhana	0.7 km
Subid-Bazar to Ambarkhana	3 km
Subid-Bazar to Modina-Market	1.2 km
Ambarkhana to Airport Road	3.9 km
Tilagor to Ambarkhana	4 km
Humayun-Chattar to Upashahar	1.1 km
Upashahar to Naiorpul	1.1 km

APPENDIX E

Expansion Factors

Table E1: Expansion Factor (HEF)

Time	Factors
8:00 am	19.994653
9:00 am	20.351378
12:00 pm	18.056321
1:00 pm	16.142276
3:00 pm	14.779487
4:00 pm	14.615756
5:00 pm	14.402981

Table E2: Weekly Expansion Factor (WEF)

Day	Expansion Factor
Sunday	0.995
Monday	0.958
Tuesday	0.954
Wednesday	0.984
Thursday	0.906
Friday	1.200
Saturday	1.073

Table E3: Monthly Expansion Factor (MEF)

Month	Factors
January	1.05
February	1.034
March	0.983
April	0.976
May	0.966
June	1.026
July	0.991
August	1.027
September	0.951
October	1.036
November	1.016
December	0.958