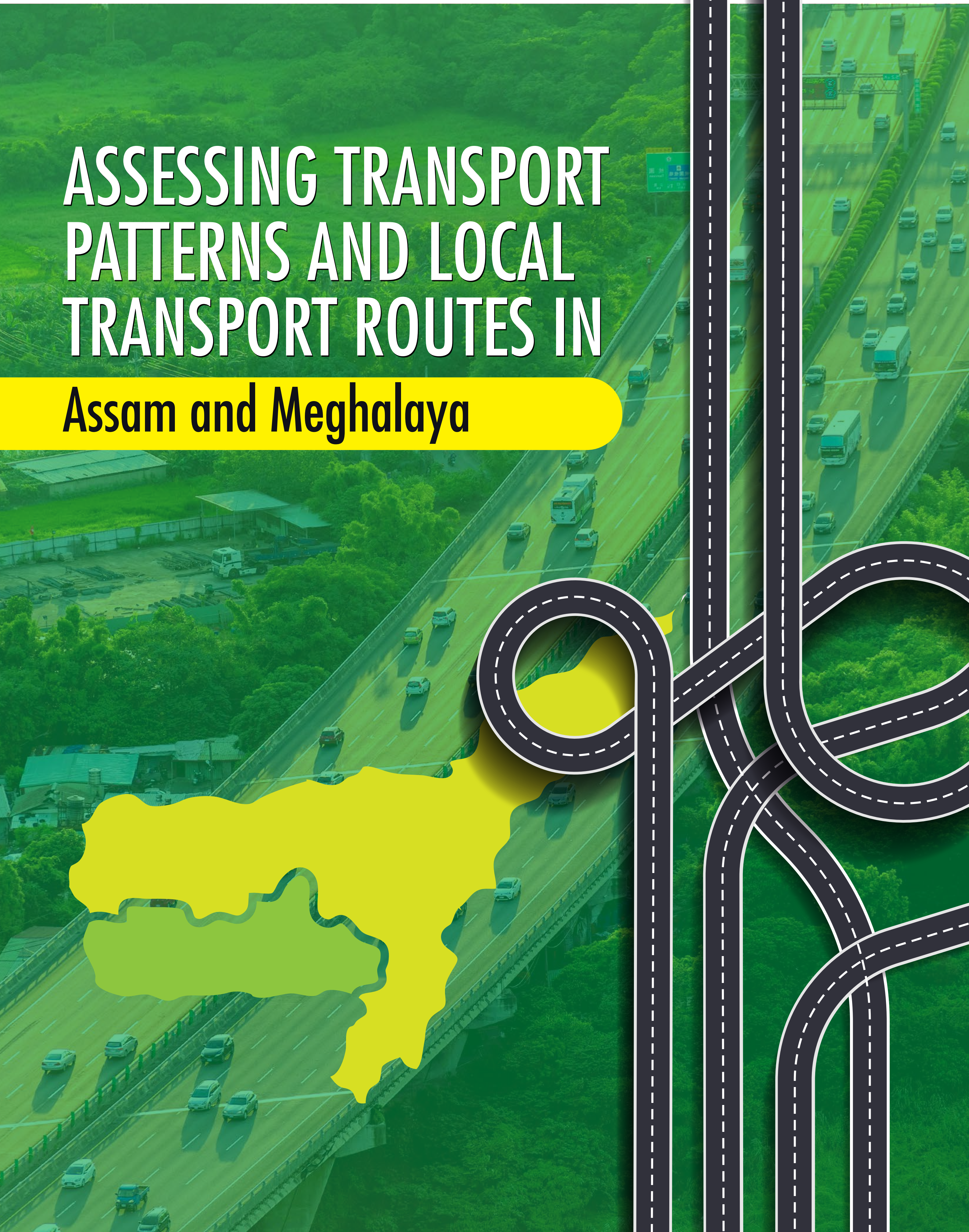
Alliance for an™ Energy Efficient Economy

ASSESSING TRANSPORT PATTERNS AND LOCAL TRANSPORT ROUTES IN

Assam and Meghalaya



ASSESSING TRANSPORT PATTERNS AND LOCAL TRANSPORT ROUTES IN

Assam and Meghalaya

Prepared by: Alliance for an Energy Efficient Economy (AEEE)

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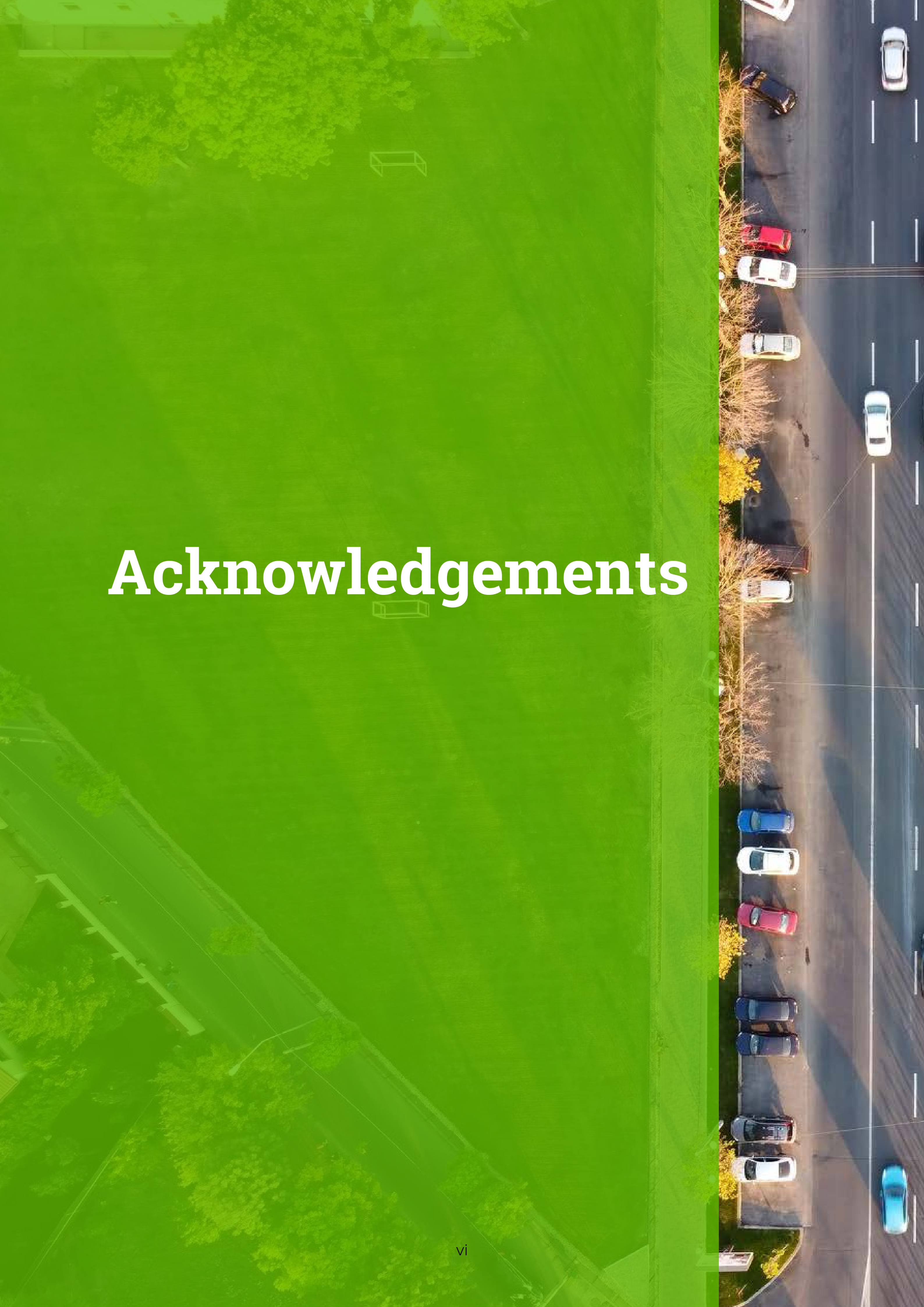

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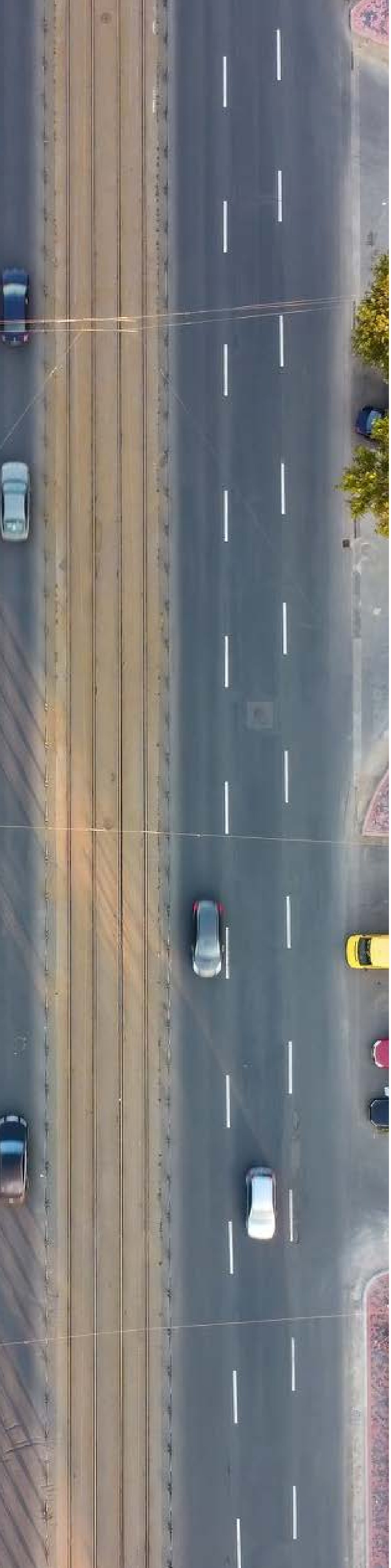

We express our deepest appreciation to both the Meghalaya Transport Department and the Assam State Transport Corporation (ASTC) for their exceptional support and invaluable contributions to this report. Their guidance, insights, and unwavering commitment were instrumental in our comprehensive study of transport patterns and challenges in Assam and Meghalaya, with a particular focus on road transport infrastructure and its impact on travel behavior.

Special recognition goes to Mr. Satish Kumar, President of AEEE, for his invaluable guidance and feedback. His extensive knowledge in the field of energy efficiency has been a guiding light throughout our research.

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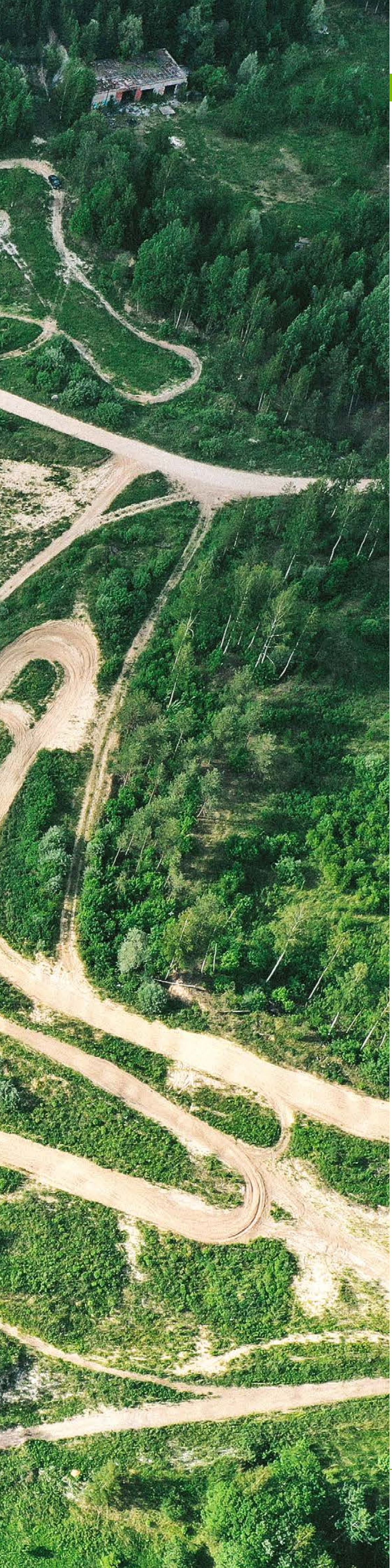
We are thankful to all the stakeholders who actively participated and provided their valuable insights. Their perspectives were essential in enriching our understanding of the transportation dynamics in Assam and Meghalaya. The success of this report is also attributed to the dedication and expertise of various speakers, participants, and stakeholders. Their engagement and insights into complex issues such as energy efficiency, traffic congestion, pollution, and electrification options have been invaluable.

In conclusion, we express our profound gratitude to everyone involved in this project. Your support, expertise, and collaboration have been essential in the realization of this comprehensive report, and we are immensely thankful for your contributions to this significant endeavor.

Executive Summary



This report offers a comprehensive examination of transport patterns and local transport routes within the northeastern Indian states of Assam and Meghalaya. With a primary focus on road transport infrastructure, resulting travel behavior, and associated challenges, this study aims to provide valuable insights into the current state of transportation in these regions and explore the potential benefits of electrification as a solution.

The purpose of this study is twofold: firstly, to assess the existing transport patterns in Assam and Meghalaya, and secondly, to investigate the feasibility of electrification to address the various transportation-related issues these states face. Assam and Meghalaya, with their distinct geographical and cultural characteristics, present unique challenges in terms of transportation. Understanding the transport dynamics in these states is crucial for effective planning and development. The primary objective of this study is to gain a deep understanding of the current transportation infrastructure in Assam and Meghalaya, particularly the road networks, and to identify opportunities for electrification to combat issues like pollution, traffic congestion, and fuel consumption.

Chapter 1 depicts the rich histories and diverse demographics possessed by both the states- Assam and Meghalaya. Assam, situated in the northeastern part of India, is characterized by its lush tea plantations and significant agricultural output. In contrast, Meghalaya, known as the "Abode of Clouds," features stunning hills and a distinctive tribal culture. The unique geographical features of these states contribute to specific transportation challenges that necessitate in-depth, evidence-based investigation. While this study strives for comprehensiveness, it acknowledges the constraints imposed by budget, time, and the vastness of the regions under consideration. The primary focus remains on road transport, recognizing the complexity of examining all transportation modes and sub-regions within Assam and Meghalaya.

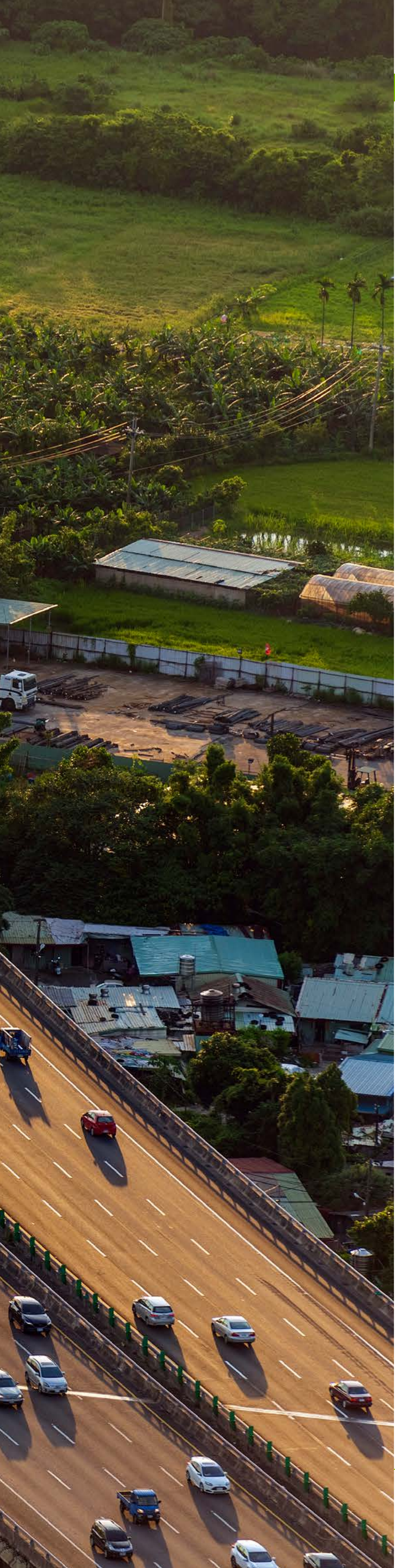
Chapter 2 provides an extensive overview of the existing transportation infrastructure in Assam and Meghalaya, specifically emphasizing road networks and other relevant transport characteristics. The road network is the lifeblood of transportation in Assam and Meghalaya. We delve into the types of roads (including the hierarchy), from highways to arterial roads and rural routes, examining their connectivity and accessibility within the states. To paint a comprehensive picture of transportation, we explore the various modes of transport operating in these states. This includes both passenger and freight transport modes. Understanding the mix of transportation modes is vital to assessing the overall transportation landscape. Understanding the road network's intricacies is vital for comprehending the challenges and potential opportunities it presents. The report highlights key issues and components associated with roads and the modal split of both states and evaluates their condition, serving as a crucial baseline for further analysis.

Chapter 3 discusses the current road transport, including its role in employment generation, its environmental impact through pollution analysis, the extent of traffic congestion, and patterns of fuel consumption, which is addressed in the report. It is worth noting that road transport has a significant impact on job creation within the study region, thus influencing the local economy and livelihoods. Environmental concerns related to road transport, such as air and noise pollution, are critical issues. An in-depth analysis of these concerns, highlighting their effects on public health and the environment, is also studied. The extent of traffic congestion in Assam and Meghalaya is a key challenge that affects the efficiency of transportation. Evaluation of the causes and consequences of traffic congestion, informing potential solutions, is also explored. Understanding fuel consumption patterns is essential for assessing the energy efficiency of the current transportation system. A brief analysis of fuel consumption trends and their implications for both states has been done.

Chapter 4 attempts to bring forth the potential solutions, particularly electrification, as a means to address the identified transportation challenges. To explore the feasibility and impact of electrification, we identify high-impact scenarios that consider the unique characteristics of Assam and Meghalaya. Each electrification scenario is analyzed in terms of its potential benefits, including improvements in air quality, increased power demand and generation capacity, and considerations regarding policy and regulation. In conclusion, this report provides a comprehensive assessment of transportation patterns and challenges in Assam and Meghalaya, proposing electrification as a viable solution to mitigate these challenges.

Chapter 5 succinctly summarizes the findings to create informed decision-making for policymakers, stakeholders, and the community at large, guiding the development of sustainable and efficient transportation systems in the region. By addressing the unique transportation issues in Assam and Meghalaya, we can work towards improving the quality of life and fostering economic growth in these states.

Acronyms



2W	:	Two-wheeler
3W	:	Three-Wheeler
AEEE	:	Alliance for an Energy Efficient Economy
AQI	:	Air Quality Index
CNG	:	Compressed Natural Gas
CO	:	Carbon Monoxide
CO2	:	Carbon Dioxide
CPCB	:	Centre of Pollution Control Board
E2W	:	Electric Two-Wheeler
E3W	:	Electric Three-Wheeler
EV	:	Electric Vehicle
FAME	:	Faster Adoption and Manufacturing of Electric and Hybrid Vehicles
GOI	:	Government of India
ICE	:	Internal Combustion Engine
INR	:	Indian Rupee
Kg	:	Kilogram
Km	:	Kilometer
KW	:	Kilowatt
KWH	:	Kilowatt Hour
LCV	:	Light Commercial Vehicle
LEV	:	Light Electric Vehicle
MDR	:	Major District Road
MNREDA	:	Meghalaya New and Renewable Energy Development Agency
NAMP	:	National Air Monitoring Programme
NH	:	National Highway
NHAI	:	National Highway Authority of India
NOX	:	Nitrogen Oxides
OEM	:	Original Equipment Manufacturer
PM	:	Particulate Matter
PPAC	:	Petroleum Planning and Analysis Cell
SH	:	State Highway
VOC	:	Volatile Organic Compounds

01

Introduction

The report attempts to provide a comprehensive analysis of the transportation systems within the states of Assam and Meghalaya. Efficient transportation infrastructure and networks play an important role in fostering economic growth, enhancing accessibility, and improving the overall quality of life for the residents. This report seeks to delve into the intricacies of road transport patterns, as well as the local transport routes that facilitate movement within urban and rural areas. By examining factors such as connectivity, accessibility, and infrastructure quality, this study aims to shed light on the current state of transportation in both states and identify areas for improvement. Additionally, the report will explore the socioeconomic impacts of the existing transport systems on the local populace, considering how transportation availability influences factors such as employment, healthcare, and social interactions. Through a comparative analysis of transportation systems in Assam and Meghalaya, this report strives to offer insights and recommendations that can contribute to the enhancement of local transport networks, ultimately contributing to the overall development and well-being of the regions.

1.1 Purpose of the Study

The purpose of this project is to comprehensively analyze and evaluate the existing transport patterns and local transport routes within the states of Assam and Meghalaya, with the aim of enhancing transportation efficiency, accessibility, and sustainability. By conducting a thorough assessment of the current transportation infrastructure, routes, and modes of transportation, this project seeks to identify opportunities for improvement, address challenges, and propose strategic interventions to optimize the overall transport network in the region.

1.2 Background of Assam

Assam, located in northeastern India, stretches across 78,438 square kilometers, catering to a population of 312,05,576 (Census 2011). It lies south of the eastern Himalayas and is positioned alongside the valleys of the Brahmaputra and Barak Rivers. The state shares its borders with various regions: Bhutan and Arunachal Pradesh to the north, Nagaland and Manipur to the east, Meghalaya, Tripura, Mizoram, and Bangladesh to the south. It's also connected to West Bengal in the west through the Siliguri Corridor, a 22-kilometer-wide strip of land that links Assam to the rest of India.

Assam has seen significant improvements in its connectivity recently, and it remains one of the states with high road density (PWD road density in Assam is 62.08 Km per 100 Sq Km.). This means that it's become much easier for people and things to move around. The roads, like highways, are well-built and go to many places, from big cities to small villages. Trains also run through Assam, connecting it to other important parts of the country. The airport in Guwahati provides air connectivity to India and a few other countries. The Brahmaputra River provides connectivity through boats and ships, which helps with trading and moving things.

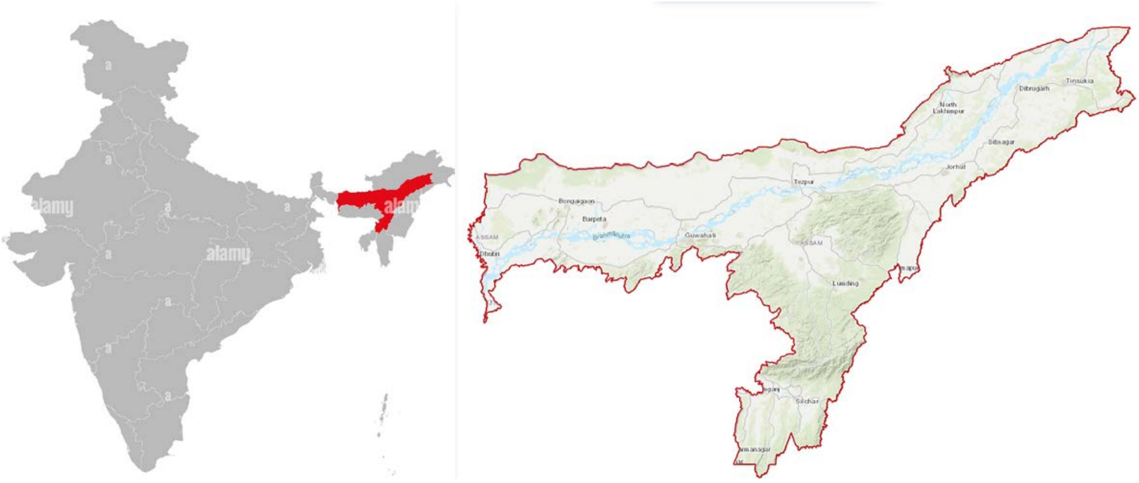


Figure 1: Map of Assam

1.3 Transport infrastructure in Assam

Assam has a large network of national highways to facilitate connectivity within and in other neighboring states. The national highways in Assam cover a total network length of 3900.44 km. This constitutes 15 newly declared National Highways of length 1032.17 km.

Table 1: Road Lengths under different organizations in Assam

Organizations managing Roads	Length (in Km)
Assam PWD	2541.937
NHAI	696.308
National Highway Infrastructure Development Corporation Ltd.	399.36
Border Road Organization	31
Railways	13.65
Ministry of Road Transport & Highways	25.807
Newly Declared NHs but yet to be entrusted	192.38

Source: pwdbnh.assam.gov.in

The state encompasses a total of 135 stations and three Interstate Bus Terminals. Its transportation fleet consists of over 1100 buses, accompanied by an additional fleet of more than 1200 privately owned buses that operate under the ASTC banner. (Govt. of Assam)

1.4 Background – Meghalaya

Meghalaya, also located in northeastern India, stretches across 22,429 square kilometers, catering to a population of 312,05,576 (Census 2011). Shillong serves as the capital of Meghalaya. The state shares its southern border with the Bangladeshi regions of Mymensingh and Sylhet, while its western border is connected to the Bangladeshi division of Rangpur. To the north and east, it is bordered by India's Assam state, and with Bangladesh's divisions of Mymensingh, Sylhet, and Rangpur to the south and west. Furthermore, Meghalaya's proximity to Assam has made railway connectivity a crucial element.

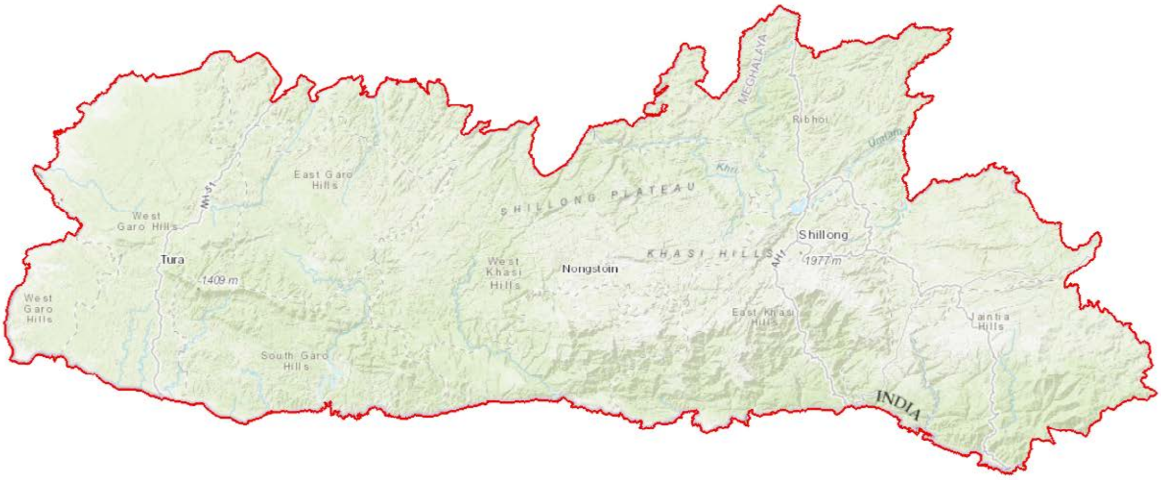


Figure 2: Map of Meghalaya

1.5 Transport infrastructure in Meghalaya

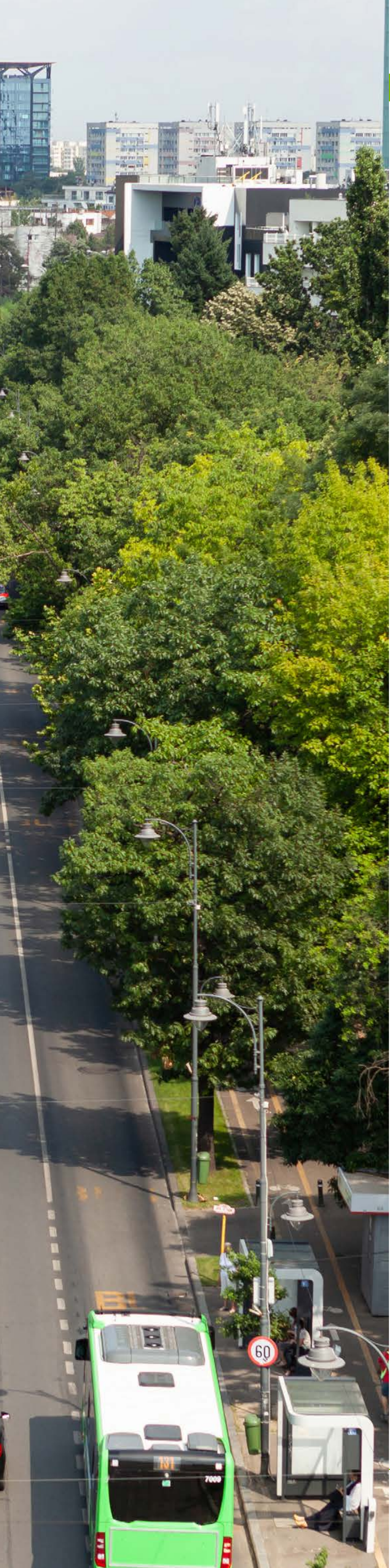
When Meghalaya gained autonomous state status in 1970 by separating from Assam, it inherited a combined road length of 2786.68 kilometers, which included 174 kilometers of National Highways. The road density at that time was 12.42 kilometers per 100 square kilometers. Substantial progress has been achieved since achieving statehood. By the end of the 12th Five-Year Plan, the total road length had increased significantly to 10,487.094 kilometers. This total included 7460.201 kilometers of surfaced roads and 3026.893 kilometers of unsurfaced roads. Although the road density figure still falls well short of the national average (170 kilometers per 100 square kilometers), the current value for Meghalaya stands at 46.76 kilometers per 100 square kilometers (Govt. of Meghalaya). Also, the state is having 6 National Highways covering a total length of 1124.39 Km, out of which 753.13 Km is maintained by State PWD, NHAI maintains 214.56 Km, and 156.70 Km is maintained by NHIDCL.

1.6 Scope and Limitations of the Study

The study aims to comprehensively analyze transportation systems in both states, including travel patterns, routes, infrastructure, and socioeconomic impacts. However, potential limitations such as data availability, time constraints, regional scope, weather influences, qualitative factors, and policy changes should be considered when interpreting the findings. Despite these limitations, the study strives to provide valuable insights for informed decision-making to enhance the local transport systems in Assam and Meghalaya.

02

Transport Patterns in Assam and Meghalaya



2.1 Overview of Current Transport Infrastructure

The body of research dedicated to the exploration of transportation challenges and dynamics in Assam and Meghalaya offers a comprehensive overview of the multifaceted aspects of the region's transport infrastructure. Several key studies have delved into various dimensions of the transport landscape, shedding light on the persisting issues and potential solutions.

The transport sector in the region has come under analysis due to its significant impact on safety, mobility, and overall urban development. A study conducted by Das & Mitra (2017) sheds light on the intricate challenges arising from rapid development and motorization in the region. The escalating prevalence of vehicles and inadequately planned road systems have adversely affected pedestrian safety and mobility. Issues such as limited road space, uncontrolled traffic management, and abrupt land use changes have contributed to the deterioration of conditions for pedestrians. Accidents and congestion have become rampant, aggravated by factors like disorganized street parking, absence of proper street infrastructure, and lack of road signals. An underlying concern highlighted in the studies is the inadequate implementation and maintenance of government schemes and policies aimed at improving transportation conditions. The deterioration of transportation conditions has far-reaching consequences, exacerbating existing problems. According to surveys conducted, more than three-quarters of the respondents have described the current situation as chaotic and accident-prone. The migration of people from rural to urban areas in search of better opportunities has fueled the demand for private vehicles, contributing to the growing vehicular density. However, the lack of proper public transport infrastructure and management has resulted in the unchecked growth of private vehicles, exacerbating congestion and pollution.

In conclusion, the transport sector in the region faces complex challenges stemming from rapid urbanization, inadequate infrastructure, and lack of effective traffic management. As vehicle numbers rise and urban development intensifies, the need for comprehensive solutions becomes more pressing. Strategies that encompass well-planned infrastructure, technological integration, and robust policy implementation are essential to alleviate the adverse effects of traffic congestion and ensure the safety and mobility of all stakeholders in the region.

2.2 Road Network

2.2.1 Types of Roads (Highways, Arterial Roads, Rural Roads)

ASSAM

The total road network in the State of Assam is 3,99,122 km in length, which constitutes 7.73% of the total road length of Indian road network. As per the types of roads classification, total road network can be classified as National Highways, State Highways and major district roads followed by a lower hierarchy of roads such as village roads and local roads, wherein 3,909 km is constituted as National Highways in Assam, followed by 2,530 km road length under State Highways and 6,093 km as major district roads. The rest 3,72,510 km of road falls under the category of rural roads and 6,268 km of road as urban roads.

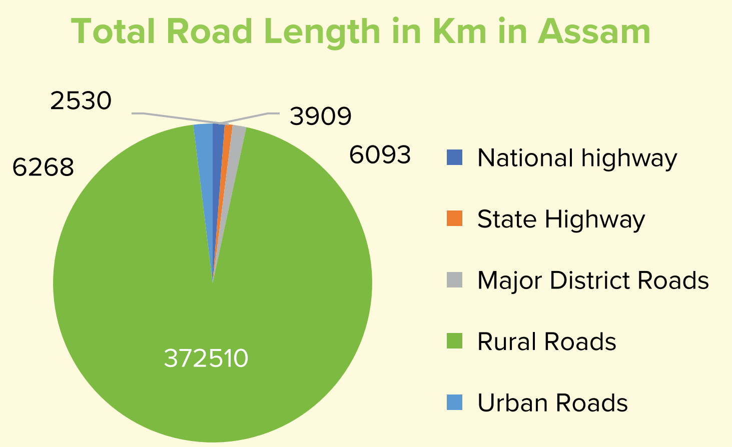


Figure 3: Road Hierarchy of Assam

Source: Basic Road statistics of India, 2016-17

MEGHALAYA

The total road network in the State of Meghalaya is 40,258 km in length, which constitutes 0.77% of the total road length of the Indian road network.

As per the types of road classification, the total road network can be classified as National Highways, State Highways, and major district roads, followed by a lower hierarchy of roads such as village roads and urban local roads, wherein 1,516 km is constituted as National Highways in Meghalaya, followed by 768 km road length under state Highways and 4,624 km as major district roads. The rest, 32,537 km of road, falls under the category of rural roads, and 571 km of road is urban.

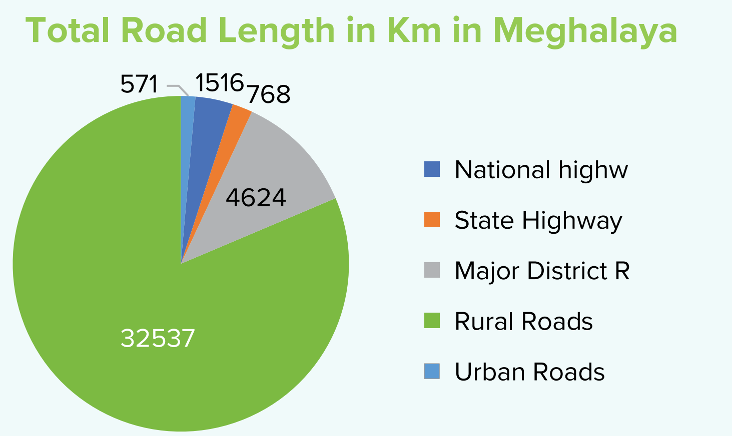


Figure 4: Road Hierarchy of Meghalaya

Source: Basic Road statistics of India, 2016-17

There is a huge difference in the total road network of Assam and Meghalaya, albeit sharing some topographical similarities, yet Assam constitutes a higher percentage of the overall road network in comparison to Meghalaya.

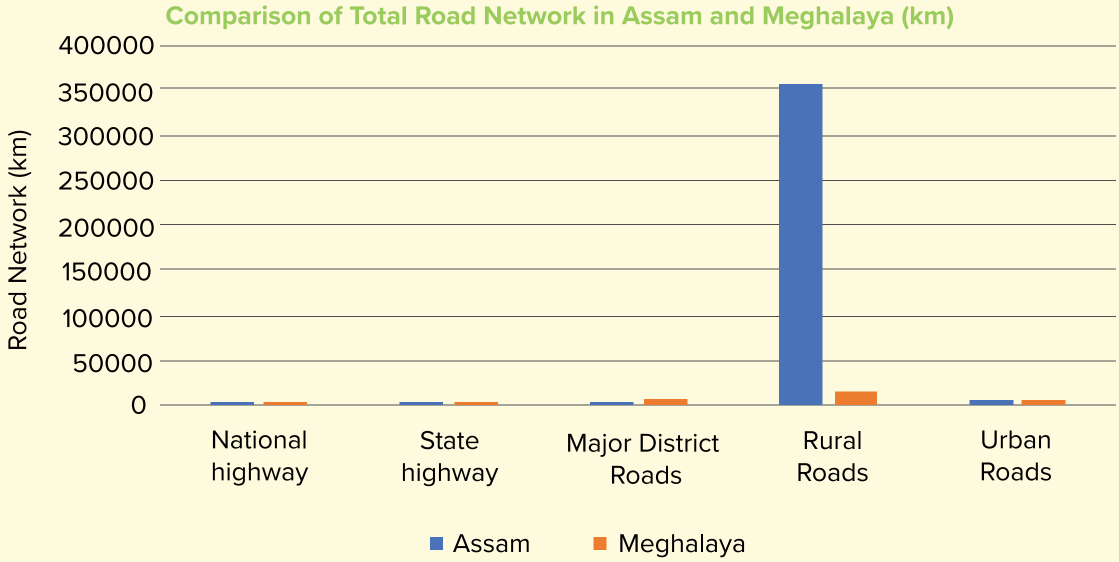


Figure 5: Comparison of total Road network of both the states

Source: Basic Road statistics of India, 2016-17

As per the hierarchical subdivision within the road network of both states, Meghalaya constitutes of more major district roads in comparison to Assam whereas National Highways, State highways and urban and rural local roads of Assam exceed in number in comparison to Meghalaya. Assam rural road length exceeds exponentially in comparison to not only Meghalaya but rest of the states as well, according to the statistics, it comes at second position after Maharashtra in the state wise distribution of local rural roads.

2.2.2 Connectivity and Accessibility

ASSAM

A comprehensive study titled "Traffic Survey at Tezpur Town of Assam, India" was conducted by Hazarika, Hazarika, Das, & Choupash, 2019 noted that Tezpur town, nestled in Assam and serving as the administrative hub of Sonitpur district, exhibits cultural significance and modern amenities. Positioned along the northern bank of the Brahmaputra River, the town experienced rapid growth, boasting accessibility by road, rail, and air. A recent journal paper by Sharma & Sengupta, 2018 delved into the issue through three principal lenses: traffic congestion, parking challenges, and deficient public transportation. The report unveiled that a substantial 82% of Guwahati residents encounter daily traffic jams, with around 9.3% spending over an hour each day grappling to reach their destinations. The lack of parking spaces within the city adversely affects urban dwellers, causing an inclination among car owners (20%) to abstain from utilizing their vehicles due to the daunting parking scenario. Notably, 36.3% continue to use their vehicles, while 43.7% navigate the city. Notably, four-wheelers experience more pronounced traffic congestion than two-wheelers, largely attributed to insufficient parking availability and poor accessibility to predominant land uses.

While the vehicle count has surged, the road capacity has remained unaltered. Effective traffic management hinges on adherence to regulations and appropriate parking practices. Public areas interconnected with commercial establishments like shops and restaurants often lack designated parking spaces, exacerbating the predicament. Remedies such as constructing more flyovers (49.3%) and widening roads (40.2%) have been proposed. Approximately 51.4% expressed dissatisfaction with the cities' public transport system, which inadequately covers all areas. While city buses are confined to major roads, smaller routes are primarily serviced by cabs, particularly after 9 pm when public transport becomes scarce. Although private ride-sharing options like Ola and Uber are available, they are not cost-efficient. Respondents highlighted the need for cost-effective government-run buses to operate late at night, catering to the populace's transport needs during extended hours.

MEGHALAYA

The study conducted by Chutia, Nongkynrih, Das, & Barman, 2006 highlighted the issue of inadequate road connectivity in rural areas despite development efforts. Inadequate road infrastructure isolated many regions, hindering connections between remote and urban areas. Roads emerged as vital for various sectors such as agriculture, healthcare, education, and driving development. However, the Northeastern states, including Meghalaya, faced challenges in establishing robust road connectivity with the rest of the country. Deficient road infrastructure and transportation management impeded overall progress, particularly affecting rural socio-economic conditions. Over time, conditions have improved with better connectivity, but congestion remains a major issue..

Ri Bhoi District in Meghalaya, covering an area of 2448 sq. km with a population of 2,58,7840 as per the 2011 census, demonstrated a deficiency in transportation and communication facilities when compared to Shillong City. With only NH40 as the sole National Highway traversing the district. Effective transport services facilitated access to essential amenities like healthcare centers, markets, and schools. Ri Bhoi District, with limited transportation and communication facilities compared to Shillong City, demonstrated the need for improved infrastructure. Geographical constraints, except in Assam, led to prevalent road usage due to limited alternatives like railways and waterways.

This challenging terrain in the region contributed to inadequate road connectivity, resulting in rural socio-economic stagnation. The study underlined the importance of addressing these challenges, suggesting Geographic Information Systems (GIS) for road transport planning to enable informed decision-making through mapping, charting, and network-level analysis. The escalating expansion of road networks, together with the surging volume of commuter vehicles, has become a predominant concern for citizens in Assam and Meghalaya.

2.3 Transport Characteristics

2.3.1 Trends in passenger and freight transport

Trends in passenger and freight transport were observed through the last five year's vehicular registration data obtained from Vaahan Dashboard for the states of Assam and Meghalaya.

ASSAM

In Assam, for passenger vehicles, a decline in the total number of two-wheelers was observed for the years 2020 and 2021, possibly due to the COVID-19 pandemic. Other vehicle categories observed a similar trend in the last five years.

Table 2: Assam - Passenger vehicular trend (2018-2022)

Year	Heavy Motor Vehicle	Heavy Passenger Vehicle	Light Motor Vehicle	Light Passenger Vehicle	Medium Motor Vehicle	Medium Passenger Vehicle	Three Wheeler	Two Wheeler	Others
2018	129	588	69644	6974	17	439	23498	370967	185
2019	124	585	68822	6249	36	452	27334	377629	203
2020	109	255	65146	1696	68	135	16907	291687	238
2021	67	208	70990	1453	64	138	21180	336353	787
2022	99	279	82085	3002	64	311	46233	349749	1054

Source: Vaahan Dashboard

In the case of freight vehicles, a sharp decline has been observed in the case of light goods vehicles, which were a total of 40,214 in 2018 and were observed to be just 28,250 for 2022. Also, Medium goods vehicles had a sharp decline from a total of 1,035 vehicles in 2021 to 429 vehicles in 2022. Heavy good vehicles were observed to have a steady trend in the last five years.

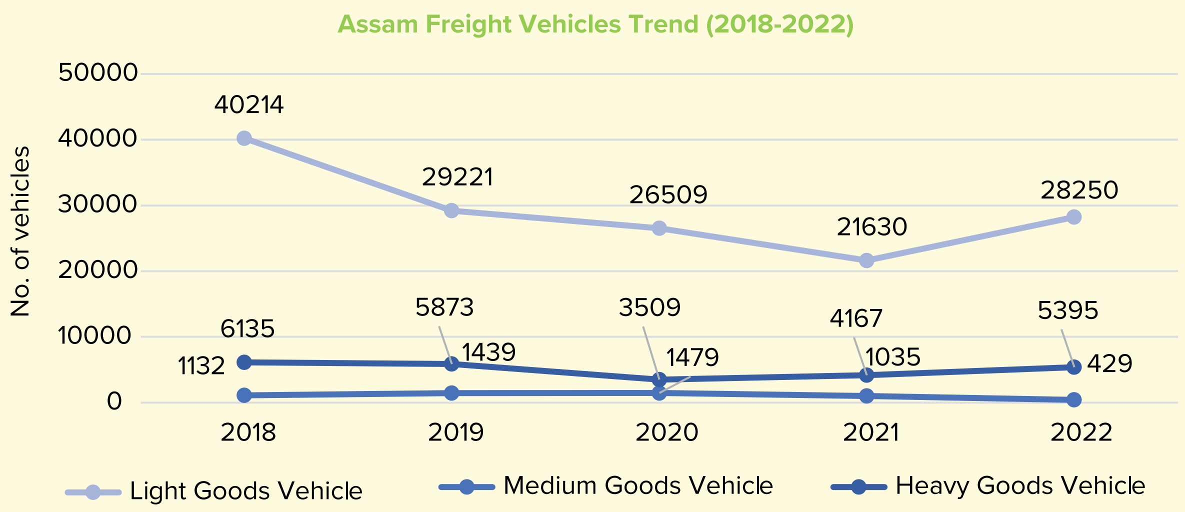


Figure 6: Assam - Freight vehicular trend (2018-2022)

Source: Vaahan Dashboard

MEGHALAYA

In Meghalaya, for passenger vehicles, a decline was observed for the Light Motor Vehicles category and Two Wheelers for the year 2020 due to the COVID-19 pandemic. Other vehicle categories observed a similar trend in the last five years.

Table 3: Meghalaya - Passenger vehicular trend (2018-2022)

Year	Heavy Motor Vehicle	Heavy Passenger Vehicle	Light Motor Vehicle	Light Passenger Vehicle	Medium Motor Vehicle	Medium Passenger Vehicle	Three Wheeler	Two Wheeler	Others
2018	10	12	10016	1772	33	33	928	17330	195
2019	7	17	9482	2198	40	40	922	16537	252
2020	9	4	8217	1318	20	20	478	10499	270
2021	11	1	8559	1075	7	7	373	12842	271
2022	6	21	11071	2030	7	16	462	17483	291

Source: Vaahan Dashboard

In Meghalaya, for freight vehicles, a decline was observed for the Light, Medium, and Heavy Goods Vehicles category for the year 2020 and 2021 due to the COVID-19 pandemic, followed by a rise in total vehicles registered for the year 2022.

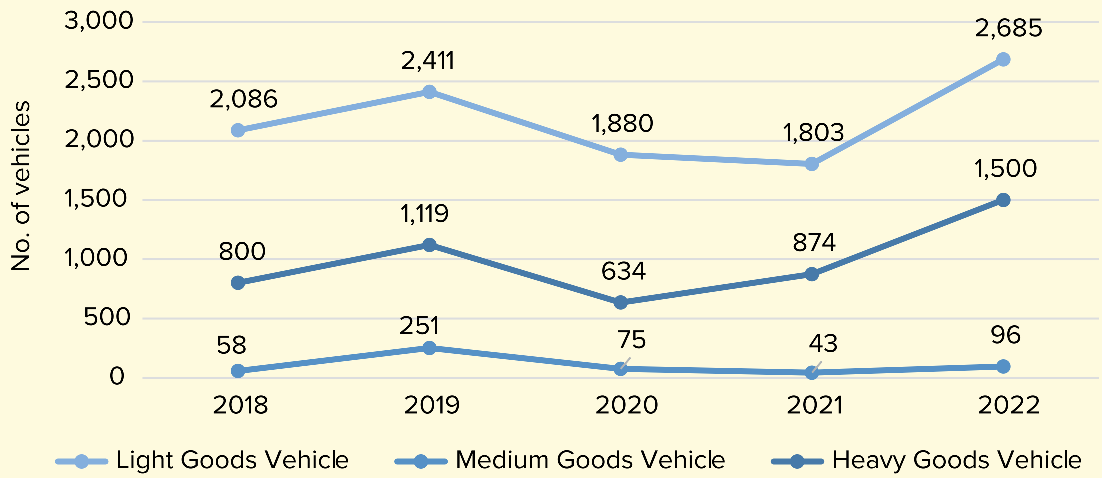


Figure 7: Meghalaya - Freight vehicular trend (2018-2022)

Source: Vaahan Dashboard

Examining passenger and freight transport trends within the states of Assam and Meghalaya from 2018 to 2022 reveals a dynamic landscape. The growth in the vehicular population was observed to have declined in 2020 and 2021 due to the pandemic. Apart from this, the growth in urbanization and rising disposable incomes in urban and peri-urban centers led to an increased demand for public and private modes of transportation, resulting in an upsurge in the usage of two-wheelers, taxis, and app-based ride-sharing services. Conversely, the rural areas of both states often remained reliant on traditional modes of transport due to limited infrastructural development. Additionally, the tourism sector played a significant role in shaping passenger transport trends, with increased domestic and international tourism driving demand for air travel and intercity connectivity.

2.3.2 Modes of Transport (Public, Private, Freight)

The analysis of transport modes and their usage patterns has been extensively studied in various studies, shedding light on the intricate interplay between urban development, transport modes, and the challenges faced by commuters and pedestrians. Das & Mitra, 2017 in their study uncovered the negative consequences of rapid urbanization and motorization on pedestrian safety and mobility. The study highlighted factors such as limited road space, unplanned vehicular movement, uncontrolled traffic management, and changing land use patterns that have led to adverse conditions for pedestrians. The poor maintenance and implementation of government schemes were highlighted as exacerbating factors.

ASSAM

The modal share of Assam comprises 3,45,559 private vehicles (majorly including four-wheelers and two-wheelers), which constitutes roughly 82% of overall total vehicles in the State of Assam, followed by 45,882 public vehicles (including buses, electric rickshaws, three-wheelers, and other intermediate public vehicles)constituting 10% of total registered vehicles and rest 29,627 freight vehicles (such as goods vehicles like LCV, road roller, crane, etc.) which only constitutes to rest 7% of the total registered vehicles.

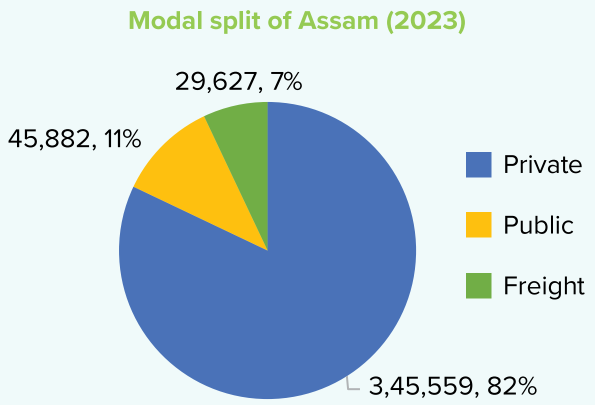


Figure 8: Modal split of Assam

Source: Vaahan Dashboard

MEGHALAYA

The modal share of Assam comprises 21,626 private vehicles (majorly including four-wheelers and two-wheelers), which constitutes roughly 80% of the overall total vehicles in the State of Assam, followed by 2,521 public vehicles (including buses, electric rickshaws, three-wheelers and other intermediate public vehicles)constituting 10% of total registered vehicles and rest 2,782 freight vehicles (such as goods vehicles like LCV, road roller, crane, etc.) which only constitutes to rest 10% of the total registered vehicles.

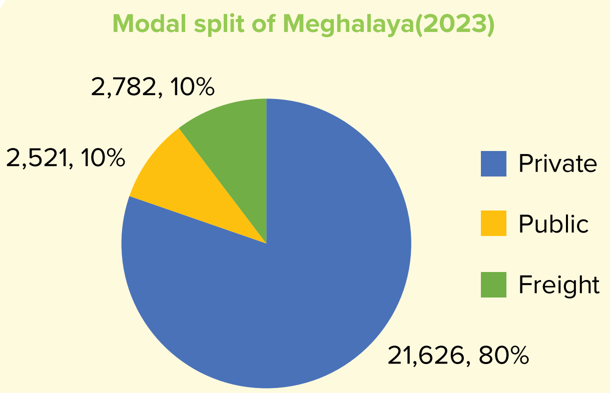


Figure 9: Modal Split of Meghalaya

Source: Vaahan Dashboard

2.4 Conclusion

The climatic conditions in these states, particularly the heavy monsoon rains, significantly impact transportation routes. The seasonal variability introduces disruptions in the form of road closures, landslides, and infrastructure damage, further shaping the choice of routes and modes of transport. Overcoming these climatic challenges requires careful planning and design to ensure the resilience of transportation networks.

Economic activities also dictate transport patterns and routes. The agricultural sector, including tea cultivation in Assam and various crops in Meghalaya, demands timely transportation to preserve the quality of perishable goods. Additionally, the growing tourism industry underscores the need for well-connected routes to facilitate the movement of visitors to various destinations, highlighting the economic importance of transportation infrastructure. Inadequate infrastructure emerges as a significant impediment to optimized transport routes. The lack of well-developed roadways, railways, and air connectivity restricts the efficiency and accessibility of transportation networks. Investment in infrastructure development becomes essential to unlocking the full potential of the transport system and opening up new route possibilities. Socio-cultural considerations add another layer of complexity to transport patterns. The presence of diverse indigenous communities with distinct mobility needs necessitates an inclusive approach to route planning, ensuring that the transportation network caters to the requirements of all segments of the population.

In summary, the transport patterns and routes in Assam and Meghalaya are a product of the interplay between geographical, climatic, economic, infrastructural, and socio-cultural factors. To design effective and resilient transportation systems, a comprehensive understanding of these factors is imperative, allowing for the creation of well-connected routes that address the unique challenges and opportunities presented by these states' distinct landscapes.

03

Characteristics of Current Road Transport

The chapter emphasizes the existing situation of road transportation and its characteristics in both the respective states, focusing entirely upon the direct and indirect impacts on employment generation, estimation of pollution through vehicles along with traffic congestion happening on major arterial roads in urban settlements as well as the estimation of fuel consumption patterns by various modes of transport.

3.1 Pollution Analysis

Analyzing pollution in the states of the North-east caused by roads and transportation involves examining various types of pollution, including air pollution, water pollution, noise pollution, and even soil pollution, that can result from vehicle emissions, traffic congestion, road dust, traffic noise, exceeding speed frictions, etc.

Air quality in Indian cities is degrading at an alarming rate. On a global basis, vehicles account for about 14-16% of carbon dioxide (CO2), 25-30% of oxides of Nitrogen (NOx), 50% of hydrocarbons (HC), 60% of Lead (Pb) and as much as 60% of carbon monoxides (CO) of the anthropogenic emissions. The CO2 emission from the transportation sector in India is growing at an alarming rate. Compared with the developing countries, CO2 emissions will be more than double by 2030. It is reported that road transportation is responsible for 80 percent of total emissions from the transportation sector.

ASSAM

A comprehensive study done by Gautam Dutta, 2016 on the topic titled “Emission Inventory of Vehicular Pollutants of Assam and Its Trend Analysis” focuses on pollution analysis specifically by vehicles registered in Assam. The data on total consumption of different fuels from 2007 to 2013 were collected from Indian Oil Corporation, Assam Oil Marketing Division, Guwahati. Furthermore, Data related to the annual utilization of buses, Omnibuses, two-wheelers, light motor vehicles (passenger), cars and jeeps, and taxis were assumed to be 100000, 100000, 6300, 33500, 12600, and 12600 km, respectively (buses, two-wheelers, car, and auto rickshaw as per Singh, 2006). Similarly, for trucks and Lorries, light motor vehicles (goods), trailers, and tractors were assumed to be 25000 to 90000, 63000, and 21000 km per year, respectively (WGRTIPC, 2007).

Table 4: Emission factors for different vehicles (gm/km)

Pollutants	Bus	Omani bases	2 Wheelers	LMV	Cars & Jeep	Jeep	Trucks	LMV Goods	Tractors & trailers	Others	Ref
CO_2	515.2	515.2	26.6	60.3	223.6	208.3	515.2	515.2	515.2	343.87	Mittal and Sharma, 2023
CO	3.6	3.6	2.2	5.1	1.98	0.9	3.6	5.1	5.1	3.86	CPCB, 2007
NOX	12	12	0.19	1.28	0.2	0.5	6.3	1.28	1.28	3.89	CPCB, 2007
CH4	0.09	0.09	0.18	0.18	0.17	0.01	0.09	0.09	0.09	0.11	EEA, 2001
SO_2	1.42	1.42	0.013	0.029	0.053b	10.3c	1.42	1.42	1.42	1.94	Kandlikkar and Ramachandran, 2000
PM	0.56	0.56	0.05	0.2	0.03	0.07	0.28	0.2	0.2	0.24	CPCB, 2007
HC	0.87	0.75	1.42	0.14	0.25	0.13	0.87	0.14	0.14	0.54	CPCB, 2007

Source: (Gautam Dutta, 2016)

Table 5: Total vehicular emissions from year 2007 to 2013 of Assam (mg/km)

Year	CO	CH_4	SO_2	PM	HC	NO_x	CO_2
2007	8234	408	1876	442	2520	8094	659786
2008	11788	598	2595	616	3654	11176	945748
2009	13574	697	2929	698	4267	12593	1040018
2010	14888	768	3194	758	4674	13603	1130769
2011	16934	869	3638	864	5392	15508	1296596
2012	19071	981	4088	967	5959	17366	1455176
2013	20847	1068	4502	1056	6369	19051	1600459
Growth Rate	109	109	110	109	107	110	110

Source: (Gautam Dutta, 2016)

It revealed that all the pollutants have more than doubled in these years. The highest emission values were found in the case of CO2, followed by CO and NOx. The lowest emission values over the years were estimated for suspended particulate matter (PM) and CH4. However, the overall growth rates for all the pollutants are of similar pattern.

MEGHALAYA

The Meghalaya State Pollution Control Board is monitoring the Ambient Air Quality at 7 (seven) stations in the state under the National Air Monitoring Programme (NAMP) sponsored by CPCB. The frequency of monitoring is twice a week. Particulate Matter (PM10), Sulphur Dioxide (SO2), Oxides of Nitrogen (NO2) and meteorological parameters, viz. wind speed, wind direction, ambient air temperature, humidity, etc., The Meghalaya State Pollution Control Board is monitoring the Ambient Air Quality at 7 (seven) stations in the state under the National Air Monitoring Programme (NAMP) sponsored by CPCB. The frequency of monitoring is twice a week. Particulate Matter (PM10), Sulphur Dioxide (SO2), Oxides of Nitrogen (NO2) and meteorological parameters, viz. wind speed, wind direction, ambient air temperature, humidity, etc., were monitored at these stations.

The Annual Average concentrations of Sulphur Dioxide (SO2) and Oxides of Nitrogen (NO2) are within the prescribed standards of National Ambient Air Quality standards. Particulate Matter (PM10) levels are above the National Ambient Air Quality standards. The Air Quality Index calculated for these sites in the city shows a pleasant response, with air quality marked to be 'Good to satisfactory' (Kharmih, 2020).

3.2 Traffic Congestion

In recent years, traffic congestion has become especially acute in cities worldwide: too many vehicles on narrow roads. Traffic jams and congested roads are a daily problem. The increasing demand for mobility is also a major challenge. Rising levels of traffic bring safety, health, environmental and economic concerns. The resulting costs can be measured as incremental delay, vehicle operating costs (fuel and wear), accidents, pollution emissions, and driver stress.

The escalating expansion of road networks, together with the surging volume of commuter vehicles, has become a predominant concern for citizens in Assam and Meghalaya. A recent journal paper by Sharma & Sengupta, 2018 delved into the issue through three principal lenses: traffic congestion, parking challenges, and deficient public transportation. The report unveiled that a substantial 82% of Guwahati residents encounter daily traffic jams, with around 9.3% spending over an hour each day grappling to reach their destinations.

ASSAM

Traffic congestion is a common issue in many urban and peri-urban areas in Assam. The state's growing population, expanding urban areas, and increased vehicle ownership have contributed to traffic congestion in various cities and towns. The population of Assam has been steadily increasing, leading to more vehicles on the road and increased congestion, especially in urban centers like Guwahati.

One of the critical findings emphasizes the adverse effects of high-speed vehicles and congestion in certain areas. For instance, the Jalukbari-Maligaon area of Guwahati city, selected as a case study, experiences delayed and hazardous crossings for pedestrians due to high-speed vehicles and inadequate traffic management. The absence of proper street infrastructure, lack of traffic management, parking facilities, and road signals compound the challenges in this area. The situation is further exacerbated by issues like disorganized street parking and insufficient footpath management for hawkers. The traffic congestion issue extends beyond mere inconvenience. It significantly impacts the overall quality of life in the city, leading to mental stress, wasted time, and economic losses for city dwellers, as highlighted by Ahmed & Das, 2022.

Another study conducted by Ahmed & Das, 2022 explored the extent of traffic congestion in Guwahati, acknowledging the challenges posed by the rapid growth in population and the number of vehicles. The study emphasized that urbanization and modernization have altered transportation patterns, causing traffic congestion, inefficiencies in time management, and increased frustration among city dwellers.

MEGHALAYA

The hilly terrain of Meghalaya can limit the expansion of road infrastructure. Narrow and winding roads can make it difficult to accommodate the increasing number of vehicles. Inadequate public transportation options can lead to a higher dependency on private vehicles, exacerbating congestion. Furthermore, Insufficient parking facilities in urban areas can lead to on-road parking, reducing road capacity. Most importantly, Meghalaya relies on the transportation of goods, especially in regions bordering Bangladesh, leading to heavy commercial traffic on certain routes.

Though the number of private vehicles is rapidly growing in Shillong, so are the commercial vehicles. However, private cars and others do not circulate in the city all day long, unlike commercial mini trucks, buses, taxis, etc. These commercial vehicles crisscross the city for 12-15 hours a day and are the primary and leading reason for traffic congestion (Ranhotra, 2022).

A study conducted by Rajbongshi, impact of institutional distribution on traffic, 2020 focused on traffic congestion happening in shilling. Manual traffic volume counts have been conducted in five major locations in the city to analyze spatiotemporal variation in the movement of vehicles within the city. The counts have been conducted for 12 hours duration (7.00 A.M. to 7.00 P.M.) Results showed that the flow of traffic is concentrated in locations with the highest number of institutions surrounding it. Also, the result of Chi-square test supports the alternative hypothesis. It showed that the calculated value is greater than the critical value in all cases and, therefore, implies that locational misdistribution of government offices and institutions across these chosen points causes variation in the occurrence of traffic congestion.

3.3 Fuel Consumption Patterns

Fuel consumption depends on several factors, including the number of vehicles, the types of vehicles, road conditions, transportation patterns, and economic activities, etc. The types of vehicles on the road play a significant role in fuel consumption. Passenger cars, motorcycles, trucks, and buses all have varying fuel efficiency levels. Regions with more industrial and commercial activities often have higher fuel consumption due to the transportation of goods and services.

The quality of road infrastructure and terrain can affect fuel efficiency. Well-maintained roads and highways generally lead to better fuel economy compared to poorly maintained or hilly roads. The availability and usage of public transportation systems can impact fuel consumption. A well-developed and efficient public transit system can reduce the number of private vehicles on the road.

Fuel consumption patterns can vary between urban and rural areas. Urban areas may have more traffic congestion, which can lead to lower fuel efficiency. Fuel prices and government policies related to fuel taxation can influence fuel consumption patterns. Higher fuel prices may encourage people to use more fuel-efficient vehicles or seek alternative transportation options. Older vehicles tend to have lower fuel efficiency than newer ones. Regular maintenance can also impact fuel consumption. The use of alternative fuels, such as compressed natural gas (CNG) or electric vehicles, can influence overall fuel consumption trends.

ASSAM

The data on total consumption of different fuels from 2011 to 2023 were collected from Oil Consumption in India (niti.gov.in).)

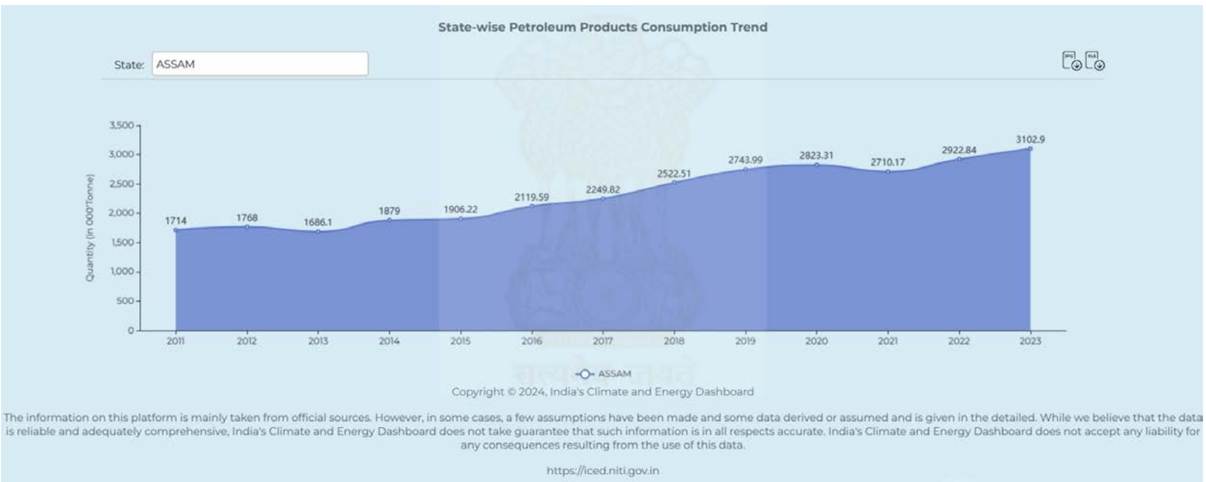


Figure 9: Petroleum Products Consumption from 2011 to 2023 in Assam

Source: Oil Consumption in India (niti.gov.in)

Consumption of petroleum products in Assam largely depends on petrol and diesel itself. From 2006 to 2023, the petroleum product consumption in the state was around 17,14,000 tonne, which increased to 31,02,900 tonne approximately within 12 years.

MEGHALAYA

As per Meghalaya New and Renewable Energy Development Agency (MNREDA), the state government of Meghalaya has roughly 150 petrol stations operational in the state with an average consumption of 6000-7000 liters of petrol and diesel.

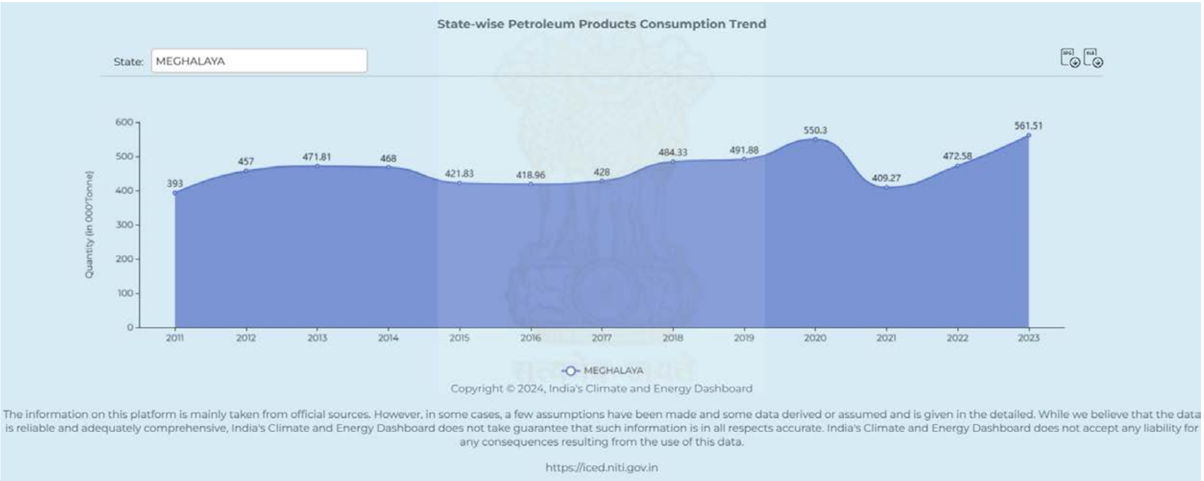


Figure 10: Petroleum Products Consumption from 2011 to 2023 in Meghalaya

Source: Oil Consumption in India (niti.gov.in)

Petroleum product consumption in Assam largely depends on petrol and diesel itself. From 2011 to 2023, the petroleum product consumption in the state was around 3,93,000 tonne, which increased to 5,61,510 tonne approximately within 12 years.

3.4 Employment Generation

Road network construction can play a significant role in employment generation in numerous ways; firstly, it provides direct employment to construction laborers, engineers, heavy equipment operators, etc. This provides direct employment opportunities to a diverse range of individuals with different skill sets and educational backgrounds. Beyond the construction phase, improved road networks can stimulate economic activity in adjacent sectors. For example, better roads can lead to increased transportation of goods, which can boost the logistics and transportation industry, creating jobs for truck drivers, warehouse workers, and logistics managers.

Road construction also drives demand for materials such as asphalt, concrete, steel, and machinery. This can lead to increased employment in the manufacturing and supply chain sectors. Suppliers of construction equipment, materials, and machinery also benefit from road construction projects. Once roads are constructed, they require ongoing maintenance and repairs. This leads to long-term employment opportunities for road maintenance crews, engineers, and inspectors.

ASSAM

The Cabinet approved the Assam Road Network Master Plan 2023 to smooth road connectivity in the state. A total of 18,421 km of roads, including 4673 km of national highways, 5120 km of state highways, and 8638 km of major district roads, will be developed under this plan. These roads will be constructed in three categories: short-term (five years), medium-term (ten years), and long-term (20 years) (Desk, 2023). It is projected to generate employment opportunities equivalent to 13 lakh people per month over 20 years of the project. (Assam Road Network Master Plan 2023 adopted to enhance transport efficiency, 2023)

The project of the road network from Bhilasipara to Sherfanguri was started in 2015 with the objective of constructing new roads spreading across the entire state and comprised of vital arteries such as NH31C, NH31, NH37, NH52, and also the stretches of Trans Asian Highway and the East-West Corridor running through Assam. Development of this core road network coupled with the development of industrial, urban, and power infra established in Assam as the centerpiece in developing northeast India as an economic hub of the region has generated employment of ~ 3.75 lakhs in the influence zone of each of the economic hub in the state.

MEGHALAYA

Meghalaya has the vision to become a high-income state by 2030, building around six pillars. The vision entails the goal of ‘decent transport for all by 2030’, which is the focus of this operation, which is the first one under the World Bank’s strategic state partnership with Meghalaya. This operation is specifically significant for the post-COVID-19 recovery period due to its employment potential and support to restore transport services, particularly for the movement of agricultural produce, and to improve the performance of transport agencies.

A limited number of highly skilled workers will be needed for construction tasks, with unskilled labor drawn from the project’s surrounding area, primarily locals. It’s worth noting that some seasonal migration occurs from the project area to other states for employment opportunities. Both men and women will be employed in road construction. Local workers are unlikely to reside in labor camps, as many will commute from home. However, skilled and semi-skilled women workers may stay in construction camps, and some will be directly or indirectly involved in construction. These workers’ families, including children, will be affected. Local women will also participate in the labor force. Recognizing women’s involvement in construction, provisions have been made for the welfare of women and children, especially during road construction.

04

Combatting issues through Electrification

Electrification can play a significant role in combating various issues discussed in previous chapter such as traffic congestion, pollution, air quality degradation through vehicular emissions, etc. in both the States. More importantly, these states are more dependent on the renewable energy sources which make EVs more viable options here. It can lead to several benefits for the transportation system including employment generation, efficiency in transport planning focusing more on sustainable resources as well as empowering existing road infrastructure.

Encouraging the adoption of electric vehicles can help reduce the number of gasoline and diesel vehicles on the road. EVs are generally quieter and produce zero tailpipe emissions, making them ideal for urban areas and reducing noise and air pollution. Government incentives and subsidies for EV purchases can incentivize individuals and businesses to switch to electric vehicles. Electrifying public transportation, such as buses and trams, can reduce the environmental impact and operational costs of these services. Efficient electric public transportation can reduce the dependency on private vehicles and ease congestion.

Developing a robust network of electric vehicle charging stations can alleviate “range anxiety” and encourage more people to switch to electric vehicles. Convenient charging infrastructure can support EV users and make electric vehicles a more viable option for daily commuting. Electric vehicles are often cheaper to operate in the long run compared to traditional internal combustion engine vehicles due to lower fuel and maintenance costs. This cost-saving potential can motivate individuals and businesses to invest in electric vehicles.

Electrification of vehicles reduces greenhouse gas emissions and local air pollution, contributing to a healthier and cleaner environment. Improved air quality can lead to better public health outcomes and reduce health-related congestion caused by illnesses. Advances in electric vehicle technology, including longer battery ranges and faster charging times, make EVs more practical for daily use. Autonomous electric vehicles may also play a role in reducing congestion by optimizing traffic flow and reducing the number of vehicles on the road.

Electrification aligns with a broader strategy of promoting sustainable transportation, which can include the development of bike lanes, pedestrian-friendly infrastructure, and the integration of various modes of transportation. Promoting alternative transportation modes can reduce the overall demand for road space. Electrification can serve as a catalyst for rethinking urban planning and transportation policies. It may lead to the development of eco-friendly urban mobility solutions and congestion reduction strategies.

In conclusion, electrification, particularly the adoption of electric vehicles and the expansion of charging infrastructure, can be a valuable tool in combating traffic issues in North-east states of India.

4.1 Identification of High-Impact Scenarios

The AEEE conducted an extensive techno-economic analysis to comprehensively assess and quantify the potential benefits of transitioning from Internal Combustion Engine (ICE) based two-wheelers, four-wheelers and buses to electric vehicles (EVs) in the states of Assam and Meghalaya. This analysis aimed to evaluate the reduction in emissions and the power demand required to charge these vehicles by the year 2030. To achieve this, three exponential vehicular growth scenarios were considered: usual, high, and very high, with growth rates set at 20%, 30%, and 50% respectively across all three modes.

In addition to assessing growth scenarios, the study also investigated three electrification scenarios: slow, medium, and high, for two-wheelers, four-wheelers and LCV's. Electrification rates were set at 30%, 40%, and 60% respectively. Furthermore, considering the government's ambitious vision for electrification, scenarios were devised for buses, with electrification rates of 30%, 50%, and 75%. These comprehensive scenarios provide a detailed understanding of the potential impacts and benefits of transitioning to electric vehicles in the region.

Benefits of Electrifying Two Wheelers

Air Quality Improvement

On average, 84 lakh g/km of carbon dioxide emission would be reduced if 20% of the registered two wheelers are electrified by 2030, followed by 2.1 lakh g/km of carbon monoxide reduction and approximately 12 thousand g/km NOX reduction by 2030. Similarly, in scenarios 2 and 3, wherein it is assumed that 40% and 60% of total two-wheelers registered till 2030, respectively, would be electrified, then there would be a huge emission reduction in carbon dioxide, carbon monoxide, and NOX, which are majorly responsible for all greenhouse gas emissions.

Table 6: Estimation of total emission reduction in different scenarios for E-Bikes

Modes	Scenarios	Additional Vehicular Growth	Total Registered Vehicles (Two Wheeler) (2030)	Emission Caused by one Vehicle (g/km)			Total Registered two-wheelers 2023 (0.54% E2W)	Current Emissions			Total Emission after Electrification of Two wheelers (g/km) (2030)								
				CO 2	CO	NOX		CO 2	CO	NO 2	CO 2	CO	NO 2	CO 2	CO	NO 2	CO 2	CO	NO 2
											30%	Electrification		40%	Electrification		60%	Electrification	
Two Wheelers	Scenario 1	20%	702502	40	1	0.06	450947	17940475	448512	26911	19670045	491751	29505	16860038	421501	25290	11240026	281001	16860
	Scenario 2	30%	761043	40	1	0.06					21309215	532730	31964	18265042	456626	27398	12176694	304417	18265
	Scenario 3	50%	878127	40	1	0.06					24587556	614689	36881	21075048	526876	31613	14050032	351251	21075

Source: Developed by Author

On average, 84 lakh g/km of carbon dioxide emission would be reduced if 20% of the registered two wheelers are electrified by 2030, followed by 2.1 lakh g/km of carbon monoxide reduction and approximately 12 thousand g/km NOX reduction by 2030. Similarly, in scenarios 2 and 3, wherein it is assumed that 40% and 60% of total two-wheelers registered till 2030, respectively, would be electrified, then there would be a huge emission reduction in carbon dioxide, carbon monoxide, and NOX, which are majorly responsible for all greenhouse gas emissions.

Power Demand and Generation

The power requirement for electric two-wheelers (e-bikes and e-scooters) can vary depending on several factors, including the vehicle's size, weight, design, and intended use. Electric two-wheelers typically have electric motors with power ratings ranging from 250 watts (0.25 kW) to 10 kW or more. Low-powered e-bikes often have motors in the range of 250 to 750 watts, which provide assistance to the rider when pedaling. E-scooters and electric motorcycles may have motors ranging from 1 kW to 10 kW or even higher for high-performance models.

The battery capacity of an electric two-wheeler is usually measured in watt-hours (Wh) or ampere-hours (Ah). The power requirement depends on the motor's power and the desired range. A higher-powered motor or longer range may require a larger-capacity battery. Hilly terrain or off-road riding of Assam and Meghalaya may require more power to handle inclines and rough surfaces.

An electric two-wheeler is assumed to get fully charged by consuming one to three units of electricity. Even high-end two-wheelers use a maximum of 3.5 units per charge. Considering these parameters and estimating power demand and generation for different scenarios for 2030 is detailed in the table below.

Table 7: Estimation of total power requirement in different scenarios for E-Bikes

Modes	Scenarios	Additional Vehicular Growth	Total Registered Vehicles (Two Wheeler) (2030)	Electricity Demand per vehicle (KWh)	Total Registered two-wheelers 2023 (0.54% E2W)	Current Electricity Demand (KWh)	Electricity Demand after Electrification of Two wheelers (g/km) (2030)		
Two Wheelers							30% Electrification	40% Electrification	60% Electrification
	Scenario 1	20%	702502	3	450947	7305	632251	843002	1264503
	Scenario 2	30%	761043	3			684939	913252	1369878
	Scenario 3	50%	878127	3			790314	1053752	1580629

Source: Developed by Author

On average, 6 lakh 32 thousand kWh of electricity will be required to fully charge 30% of the total registered two-wheelers for 2030 in scenario 1. 40% and 60% of two-wheelers would require approximately 8 lakhs and 13 lakh KWh of power to charge the vehicles effectively for smooth operation for urban commuting.

Policy and Regulatory Considerations

To promote and accelerate the adoption of electric mobility to create an ecosystem for manufacturing EV components in Assam and Meghalaya and to ensure environmental sustainability, the Governments of both States have launched the Electric Vehicle Policy, which gives certain incentives for EV adoption.

Table 8: Incentives for EV Adoption in Assam

Vehicle Segment	Battery Size in KWH (approx.)	State Subsidy Amount (Rs.)	Total Subsidy (Rs.)	Maximum ex-factory price to avail incentive (Rs.)
2 wheeler	2 KWH	10000/- per KWH	20000/-	Rs. 1.50 lakhs
3 wheeler	5 KWH	10000/- per KWH	50000/-	Rs. 5.00 lakhs
4 wheeler	15 KWH	10000/- per KWH	150000/-	Rs. 15.00 lakhs

Source: Assam Electric Vehicle Policy,2021

The Demand Incentive from the State shall be over and above any subsidies that are available from the Central Government through its promotional schemes and policies. The subsidy shall be disbursed directly to the customer via DBT mode from the State Transport Department on authenticating the document for the purchase of the vehicle.

Similar to Assam, Meghalaya also provides incentives for the purchase of electric two-wheelers, which is stated below:

"The Government shall offer a purchase subsidy @ Rs 10,000/- per KWH for the first 3500 electric two-wheelers purchased and registered in the State during the Policy period. The maximum ex-factory price to avail incentive is Rs 1.5 lakhs for electric two-wheeler vehicles."

Benefits of Electrifying Four Wheelers

Air Quality Improvement

Electrification of four-wheelers offers several significant benefits to air quality, making them a sustainable and environmentally friendly mode of transportation. Zero Tailpipe Emissions and reduced greenhouse gas emissions are the immediate and prominent benefits, followed by lower pollution concentrations in urban areas, lower noise pollution, and low dependency on fuel consumption.

Electric four-wheelers also produce zero tailpipe emissions, which means they do not emit harmful pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), or volatile organic compounds (VOCs) into the atmosphere. This is in stark contrast to traditional internal combustion engine (ICE) four-wheelers, which contribute significantly to air pollution. Electric four-wheelers are more energy-efficient than their ICE counterparts, resulting in lower carbon dioxide (CO2) emissions per kilometer traveled, especially when powered by clean electricity sources. A shift from gasoline or diesel-powered four-wheelers to electric ones can help mitigate climate change by reducing greenhouse gas emissions.

Table 9: Estimation of total emission reduction in different scenarios for E-Cars

Modes	Scenarios	Additional Vehicular Growth	Total Registered Vehicles (Cars) (2030)	Emission Caused by one Vehicle (g/km)			Total Registered Vehicles 2023 (0.24% Cars)	Current Emissions			Total Emission after Electrification of 4 Wheelers (g/km) (2030)								
				CO 2	CO	NOX		CO 2	CO	NO 2	CO 2	CO	NO 2	CO 2	CO	NO 2	CO 2	CO	NO 2
Cars											30%	Electrification		40%	Electrification		60%	Electrification	
	Scenario 1	20%	132194	110	1	0.06	88958	9761895	88745	5325	10178969	92536	5552	8724830	79317	4759	5816554	52878	3173
	Scenario 2	30%	143211	110	1	0.06					11027216	100247	6015	9451900	85926	5156	6301266	57284	5156
	Scenario 3	50%	165243	110	1	0.06					12723711	115670	6940	10906038	99146	5949	7270692	66097	3966

Source: Developed by Author

On an average 43 lakh g/km of carbon dioxide emission would be reduced if 30% of the On average, 43 lakh g/km of carbon dioxide emission would be reduced if 30% of the registered vehicles were electrified by 2030, followed by 0.39 lakh g/km of carbon monoxide reduction and approximately 2 thousand g/km NOX reduction by 2030. Similarly, in scenarios 2 and 3, wherein it is assumed that 40% and 60% of total four-wheelers registered till 2030, respectively, would be electrified, then there would be a huge emission reduction in carbon dioxide, carbon monoxide, and NOX, which are majorly responsible for all greenhouse gas emissions.

Power Demand and Generation

The power requirement for fully charging an electric four wheeler depends on three major factors that is the capacity of the battery, the state of charge (SoC) when charging begins, and the charging infrastructure's power rating.

- Battery Capacity: Electric cars are equipped with different battery sizes, with capacities typically measured in kilowatt-hours (kWh). The higher the battery capacity, the more energy it can store, and the more power it will require to charge.
- State of Charge (SoC): The starting state of charge when you begin charging the car is a crucial factor. If the car's battery is nearly empty (low SoC), it will require more energy to reach a full charge compared to a car with a higher SoC.
- Charging Speed: The charging infrastructure's power rating (measured in kilowatts or megawatts) determines how quickly the car can be charged. Faster charging stations can deliver more power, reducing the time required for a full charge.
- Charging Efficiency: The efficiency of the charging process can vary, but it typically ranges from 85% to 95%. This means that some energy is lost during the charging process due to heat and other factors.

Assuming that an average electric car capacity to be 60 kWh and State of Charge being 20% with Charging Efficiency around 90%, Total Energy required would be around = 48 kWh. Accounting charging efficiency as well, Actual energy input would be roughly 48 kWh / 0.90 = 53.33 kWh. So, to fully charge the electric car under these conditions, approximately 53.33 kilowatt-hours (kWh) of electricity is needed.

Table 10: Estimation of total power requirement in different scenarios for E-Cars

Modes	Scenarios	Additional Vehicular Growth	Total Registered Vehicles (Cars) (2030)	Electricity Demand per vehicle (KWh)	Total Registered Vehicles 2023 (0.24% Cars)	Current Electricity Demand (KWh)	Electricity Demand after Electrification of Cars (g/km) (2030)		
Cars							30% Electrification	40% Electrification	60% Electrification
	Scenario 1	20%	132194	53.33	88958	11386	2114978	2819971	4229956
	Scenario 2	30%	143211	53.33			2291226	3054969	4582453
	Scenario 3	50%	165243	53.33			2643723	3524964	5287446

Source: Developed by Author

On an average 43 lakh g/km of carbon dioxide emission would be reduced if 30% of the On average, 43 lakh g/km of carbon dioxide emission would be reduced if 30% of the registered vehicles were electrified by 2030, followed by 0.39 lakh g/km of carbon monoxide reduction and approximately 2 thousand g/km NOX reduction by 2030. Similarly, in scenarios 2 and 3, wherein it is assumed that 40% and 60% of total four-wheelers registered till 2030, respectively, would be electrified, then there would be a huge emission reduction in carbon dioxide, carbon monoxide, and NOX, which are majorly responsible for all greenhouse gas emissions.

4.1.1 Intercity Travel

Intercity travel refers to journeys between cities or urban centers, typically involving movement from one urban area to another, often located at a considerable distance apart. Road travel is a prevalent mode of intercity transportation in Assam and Meghalaya. State and national highways connect various cities and towns, making it accessible by bus, car, or motorcycle. Intercity bus services operated by both public and private companies are a common choice for affordable travel between cities. Taxis, shared cabs, and auto-rickshaws are also available for shorter intercity trips.

Some urban areas in Assam, like Guwahati, have implemented Bus Rapid Transit (BRT) systems for faster and more efficient intra city travel within urban regions. But in the case of Meghalaya, there is no public transportation available within the city. Only regional buses are operational, with no railway connectivity as well.

Approximately 10% of the vehicles in both the state of Assam and Meghalaya are comprised of Public vehicles, including all the buses, omnibuses, e-rickshaws, and three-wheelers, the rest being classified as private and freight vehicles. Under the category of public vehicles, e-rickshaws are roughly 35 thousand in number, which are currently registered in Assam, and 350 three-wheelers are registered in Meghalaya in the year 2023, whereas the total bus registered in the state is roughly 700 only.

100000 km annually is the vehicular utilization of State buses and Omni buses in Assam, whereas on average, 12600 km annually is the average utilization of four-wheelers and three-wheelers, and only 6300 km is roughly the average utilization by a two-wheeler. In terms of pollution assessment, maximum carbon dioxide and carbon monoxide are emitted from trucks followed by light commercial vehicles and buses with an approximate percentage of 40%, 25%, and 15%, respectively, as per the study conducted by Gautam Dutta, 2016 in the state of Assam.

Considering all the different parameters for the assessment of high-impact scenarios in the future run, it is evident to note that for intercity travel, electrification of state and local buses followed by three-wheelers might have a direct impact on reducing traffic pollution, noise pollution, and fuel consumption, it may also help in generating direct and indirect employment to various skilled and unskilled labors. Assam, as well as Meghalaya's State government, is also dedicated to converting all their fleet into electrified buses by 2030 as their primary objective.

Benefits of Electrifying Buses

Air Quality Improvement

Electrification of buses offers several significant benefits to air quality, making them a sustainable and environmentally friendly mode of transportation. EV buses are part of a broader strategy to promote sustainable and eco-friendly public transportation. Their adoption aligns with efforts to reduce urban congestion, encourage public transit use, and support eco-conscious urban planning.

By reducing or eliminating the emission of harmful pollutants, EV buses help improve local air quality in urban areas. Cleaner air can lead to significant health benefits, reducing the risk of respiratory and cardiovascular diseases among residents, especially vulnerable populations like children and the elderly. Electric buses are more energy-efficient than internal combustion engine (ICE) buses, as they convert a higher percentage of the energy from the grid into vehicle propulsion. Greater energy efficiency means reduced overall energy consumption and lower associated environmental impacts.

Table 11: Estimation of total power requirement in different scenarios for E-Bus

Modes	Scenarios	Additional Vehicular Growth	Total Registered Vehicles (Cars) (2030)	Emission Caused by one Vehicle (g/km)			Total Registered Vehicles 2023 (Buses 15%)	Current Emissions			Total Emission after Electrification of Buses (g/km) (2030)								
				CO 2	CO	NOX		CO 2	CO	NO 2	CO 2	CO	NO 2	CO 2	CO	NO 2	CO 2	CO	NO 2
											30%	Electrification		45%	Electrification		75%	Electrification	
Buses	Scenario 1	20%	300	822	4	0.46					172620	840	97	123300	600	69	61650	300	35
	Scenario 2	30%	325	822	4	0.46	400	279480	1360	156.4	187005	910	105	133575	650	75	66788	325	37
	Scenario 3	50%	375	822	4	0.46					215775	1050	121	154125	750	86	77063	375	43

Source: Developed by Author

On average, 1.3 lakh g/km of carbon dioxide emission would be reduced if 50% of the registered vehicles are electrified by 2030, followed by 600 g/km of carbon monoxide reduction and approximately 69 g/km NOX reduction by 2030. Similarly, in scenario 3, wherein it is assumed that 75% of total buses registered till 2030 respectively would be electrified, then there would be a huge emission reduction in carbon dioxide, carbon monoxide, and NO_x, which are majorly responsible for all greenhouse gas emissions.

Power Demand and Generation

The power requirement for fully charging an electric bus depends on three major factors that are the capacity of the bus's battery, the state of charge (SoC) when charging begins, and the charging infrastructure's power rating.

Assuming that an average bus capacity is 300 kWh (common for electric buses)and State of Charge is 20% with Charging Efficiency around 90%, Total Energy required would be around 300 kWh - (300 kWh * 0.20) = 240 kWh

Accounting for charging efficiency as well, Actual energy input would be roughly 240 kWh / 0.90 = 266.67 kWh. So, to fully charge the electric bus under these conditions, approximately 266.67 kilowatt-hours (kWh) of electricity is needed.

Table 12: Estimation of total power requirement in different scenarios for E-Bus

Modes	Scenarios	Additional Vehicular Growth	Total Registered Vehicles (Bus) (2030)	Electricity Demand per vehicle (KWh)	Total Registered Vehicles 2023 (Buses 15%)	Current Electricity Demand (KWh)	Electricity Demand after Electrification of Buses (g/km) (2030)		
							30% Electrification	50% Electrification	75% Electrification
Buses	Scenario 1	20%	300	700	400	42000	63000	105000	157500
	Scenario 2	30%	325	700			68250	113750	170625
	Scenario 3	50%	375	700			78750	131250	196875

Source: Developed by Author

On average, 63 thousand kWh of electricity is required to fully charge 30% of the total registered buses for the next 2030 years, whereas where 50% and 75% of buses would be electrified, respectively, would require approximately 1 lakh and 1.57 lakh power generation to effectively charge the vehicles for smooth operation for urban commuting.

Policy and Regulatory Considerations

"Convert 100% of public transport bus fleet into electric buses (Battery Electric Vehicles) by 2030" is the primary objective and main target listed in both the Assam Electric Vehicle Policy, 2021, and the Meghalaya Electric Vehicle Policy, 2021. Considering the existing bus fleet size of Assam and Meghalaya, roughly 20,000 buses need to be electrified for both urban and rural public transport services.

4.1.2 Freight Transport

Road transport is the primary mode of freight transportation within Assam and to neighboring states. The state has an extensive network of national highways and state roads that facilitate the movement of goods by trucks and other commercial vehicles. The National Highway 27 (NH27), NH37, and NH715 are some of the major highways passing through Assam. Assam's geography, including flood-prone areas during the monsoon season, can disrupt road and rail transportation.

The state heavily relies on various modes of transportation to facilitate the movement of goods within the state and to neighboring regions. Meghalaya does not have its own railway network, and there are no operational railway lines within the state, which creates more pressure and responsibility on road-based freight mobility only in the whole state.

Efficient freight transport infrastructure and services are critical for the economic development of Assam, Meghalaya, and the northeastern region as a whole. Investments in improving and expanding transportation networks, including roads, railways, and waterways, are essential to promote trade, create employment opportunities, and enhance the overall socio-economic development of the state. Electrification here plays an important role in further enhancing the freight demand of both the state by ensuring sustainability and reducing carbon emissions.

Approximately 10-12% of the vehicles in each of the states of Assam and Meghalaya individually comprise Freight vehicles, including all the Light commercial vehicles, multi-axle vehicles, tractor-heaving trailers, three-wheelers made for distribution of goods in local areas, etc. Rest are classified as private and freight vehicles. Under the category of freight vehicles, goods vehicles are roughly 18 thousand in number, which are currently registered in Assam and Meghalaya in the year 2023, whereas the total number of other commercial vehicles, including tractors, trailers, dumpers registered in the state is roughly 6000 only.

90000 km annually is the vehicular utilization of all types of Trucks in Assam, whereas on average, 85000 km annually is the average utilization of Trailers, and only 33600 km is roughly the average utilization by LCVs.

Considering all the different parameters for the assessment of high-impact scenarios in the future run, it is evident to note that for freight mobility, electrification of Commercial vehicles might have some impact on reducing traffic pollution, noise pollution, and fuel consumption, it may also help in generating

Benefits of Electrifying Light Commercial Vehicles

Air Quality Improvement

Electric LCVs have significantly lower fueling costs compared to their gasoline or diesel counterparts. Electricity is generally cheaper than gasoline or diesel on a per-mile basis. Electric vehicles (EVs) have fewer moving parts and simplified drivetrains, leading to reduced maintenance requirements and lower long-term maintenance costs.

Electric LCVs produce zero tailpipe emissions, which helps reduce air pollution and greenhouse gas emissions, leading to improved air quality and a smaller carbon footprint. Lower Noise Pollution: Electric vehicles are quieter than internal combustion engine (ICE) vehicles, contributing to reduced noise pollution in urban areas. Electric LCVs are more energy-efficient than ICE vehicles, converting a higher percentage of the energy from the grid into vehicle propulsion. This translates into greater mileage per unit of energy consumed. Electric LCVs may qualify for additional benefits, such as preferential parking, reduced tolls, and access to carpool lanes, further enhancing their cost-effectiveness.

Table 13: Estimation of total emission reduction in different scenarios for E-LCV

Modes	Scenarios	Additional Vehicular Growth	Total Registered Vehicles (LCVs) (2030)	Emission Caused by one Vehicle (g/km)			Total Registered Vehicles 2023 (0.05% LCV)	Current Emissions			Total Emission after Electrification of LCV's (g/km) (2030)								
					CO	NOX		CO 2	CO	NO 2	CO 2	CO	NO 2	CO 2	CO	NO 2	CO 2	CO	NO 2
											30%	Electrification		40%	Electrification		60%	Electrification	
LCV's	Scenario 1	20%	55708	100	0.12	0.056	29742	2972713	3567	1665	3899532	4679	2184	3342456	4011	1872	2228304	2674	1248
	Scenario 2	30%	60350	100	0.12	0.056					4224493	5069	2366	3620994	4345	2028	2413996	2897	1352
	Scenario 3	50%	69635	100	0.12	0.056					4874415	5849	2730	4178070	5014	2340	2785380	3342	1560

Source: Developed by Author

On average 16.7 lakh g/km of carbon dioxide emission would be reduced if 30% of the registered vehicles are electrified in 2030, followed by 2005 g/km of carbon monoxide reduction and approximately 936 g/km NOX reduction by 2030. Similarly, in scenarios 2 and 3, wherein it is assumed that 40% and 60% of total LCVs registered till 2030, respectively, would be electrified, then there would be a huge emission reduction in carbon dioxide, carbon monoxide, and NOX, which are majorly responsible for all greenhouse gas emissions.

Power Demand and Generation

The power requirement for fully charging an electric LCV depends on three major factors that is the capacity of the bus's battery, the state of charge (SoC) when charging begins, and the charging infrastructure's power rating.

Assuming that an average LCV capacity is 40 kWh and State of Charge is 20% with Charging Efficiency around 90%, Total Energy required would be around 32 kWh

Accounting for charging efficiency as well, the Actual energy input would be roughly 35.56 kWh. So, to fully charge the electric LCV under these conditions, approximately 35.56 kilowatt-hours (kWh) of electricity is needed.

Table 14: Estimation of total power requirement in different scenarios for E-LCV

Modes	Scenarios	Additional Vehicular Growth	Total Registered Vehicles (LCVs) (2030)	Electricity Demand per vehicle (KWh)	Total Registered Vehicles 2023 (0.05% LCV)	Current Electricity Demand (KWh)	Electricity Demand after Electrification of LCV (g/km) (2030)		
LCV's							30% Electrification	40% Electrification	60% Electrification
	Scenario 1	20%	55708	36.66			612672	816896	1225344
	Scenario 2	30%	60350	36.66	29742	545	663728	884971	1327456
	Scenario 3	50%	69635	36.66			765840	1021120	1531680

Source: Developed by Author

On average 6 lakh 12 thousand kWH electricity is required to fully charge 30% of the total registered goods vehicles in 2030 scenario 1 whereas, where 40% and 60% of LCVs would be electrified, respectively, would require approximately 8.16 lakh and 12.25 lakh power generation to effectively charge the vehicles for smooth operation for commuting.

4.2 Potential for Employment generation

Electric vehicles (EVs) rely on advanced battery technologies. The production of these batteries requires skilled workers in manufacturing and chemical engineering. Assembling electric cars involves a combination of robotics and human labor. Workers are needed for assembling components, quality control, and testing. Building and maintaining a network of charging stations is crucial for the widespread adoption of electric vehicles. This involves jobs in construction, electrical work, and ongoing maintenance. The transition to electric vehicles necessitates training programs for existing and new workers. This includes training mechanics to work on electric vehicles, educating sales personnel about the technology, and providing ongoing professional development.

As of public transport is concerned, the operation of electric buses requires bus drivers who are trained to handle electric vehicles. Although Support roles in the public transportation sector, such as ticketing, scheduling, and administrative positions, continue to be essential. In addition to private vehicles, Storage and management of electric bus components in warehouses provide employment opportunities.

With respect to freight vehicles, managing a fleet of e-freight vehicles involves logistics, monitoring, and coordination. Jobs can be created for fleet managers, dispatchers, and support staff. E-freight vehicles are often used for last-mile deliveries. Employment opportunities arise for delivery drivers, assistants, and logistics coordinators.

05

Conclusion

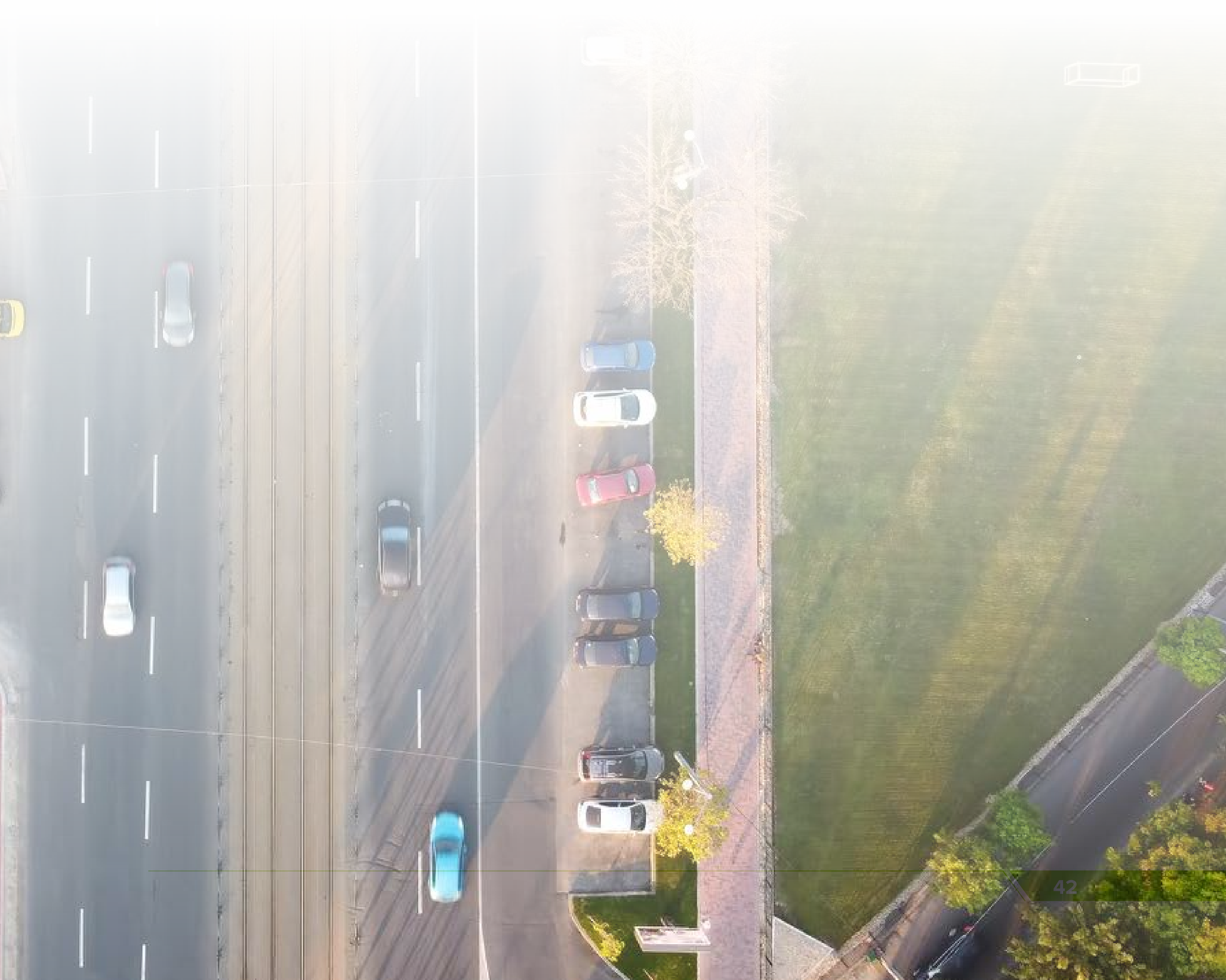
The transport patterns and routes in Assam and Meghalaya are profoundly influenced by a confluence of critical factors that reflect the unique geographic, economic, and socio-cultural landscape of these states. Geographical features play a crucial role in determining transport patterns. The challenging terrains in Meghalaya pose a significant obstacle to the establishment of efficient road networks, leading to restricted accessibility to certain areas and elevated transportation costs. Similarly, Assam's diverse topography influences the choice of routes and modes of transportation, with river networks playing a pivotal role in shaping routes and connectivity.

Road Transport in Assam is more efficient in terms of a larger road network, while increased urbanization plays a significant role in shaping the transport facilities much more vividly than in the State of Meghalaya. With respect to the modal split, both states possess similar characteristics, having an 80% share in private vehicle registration followed by the remaining 20% in public vehicles and freight vehicles. Utilization of each mode varies significantly with the purpose and function of use. For example, private vehicles have a lower rate of utilization, whereas public and freight vehicles are more focused on inter-city traveling for public transport efficiency as well as effective freight mobility, considering the logistics of both states.

Fuel consumption and air pollution analysis reveal that Assam is more prone to severe health issues caused by vehicular emissions than Meghalaya. The Air Quality Index is directly proportional to the Human Development Index (HDI) and is associated with high AQIs in Assam, directly impacting citizens' health. Meghalaya, on the other side, is directly dependent on roadways as there is no operational railway network, so all the public transportation and freight logistics happen through road-based transport within the whole state, which creates more significant highway emissions and air quality degradation, resulting in the severity of health conditions of locals.

Electrification of certain modes in different scenarios is proposed for the next two decades to achieve the targets of both the State Government EV policies as well as to promote green transport, enhancing sustainability for the longer term and improving the quality of life by shifting from ICE vehicles to electric vehicles. Since two-wheelers have the highest fleet registered in both the states, more so in Assam, we primarily focus on it, followed by four-wheelers for urban commuting in each state. At the same time, for freight mobility, priority is given to electrifying local light commercial vehicles and trucks which carry goods intra city as well as intercity in both the states for effective freight mobility. In terms of public transport, 100% of the fleet would be electrified as per the state EV policy of Assam and Meghalaya, which targets that by 2030 all public vehicles will be converted to EVs.

Most of the benefits in terms of emission reduction and air quality improvement for the State of Assam are focused on the electrification of two-wheelers followed by the electrification of four-wheelers assuming the 20% shift from ICE to electric vehicles in the high impact scenario for urban commuting. For the State of Meghalaya, prioritization should be given to the electrification of public transport and freight vehicles in terms of emission reduction, though the power requirement for four-wheelers is maximum, followed by freight vehicles and electric buses.



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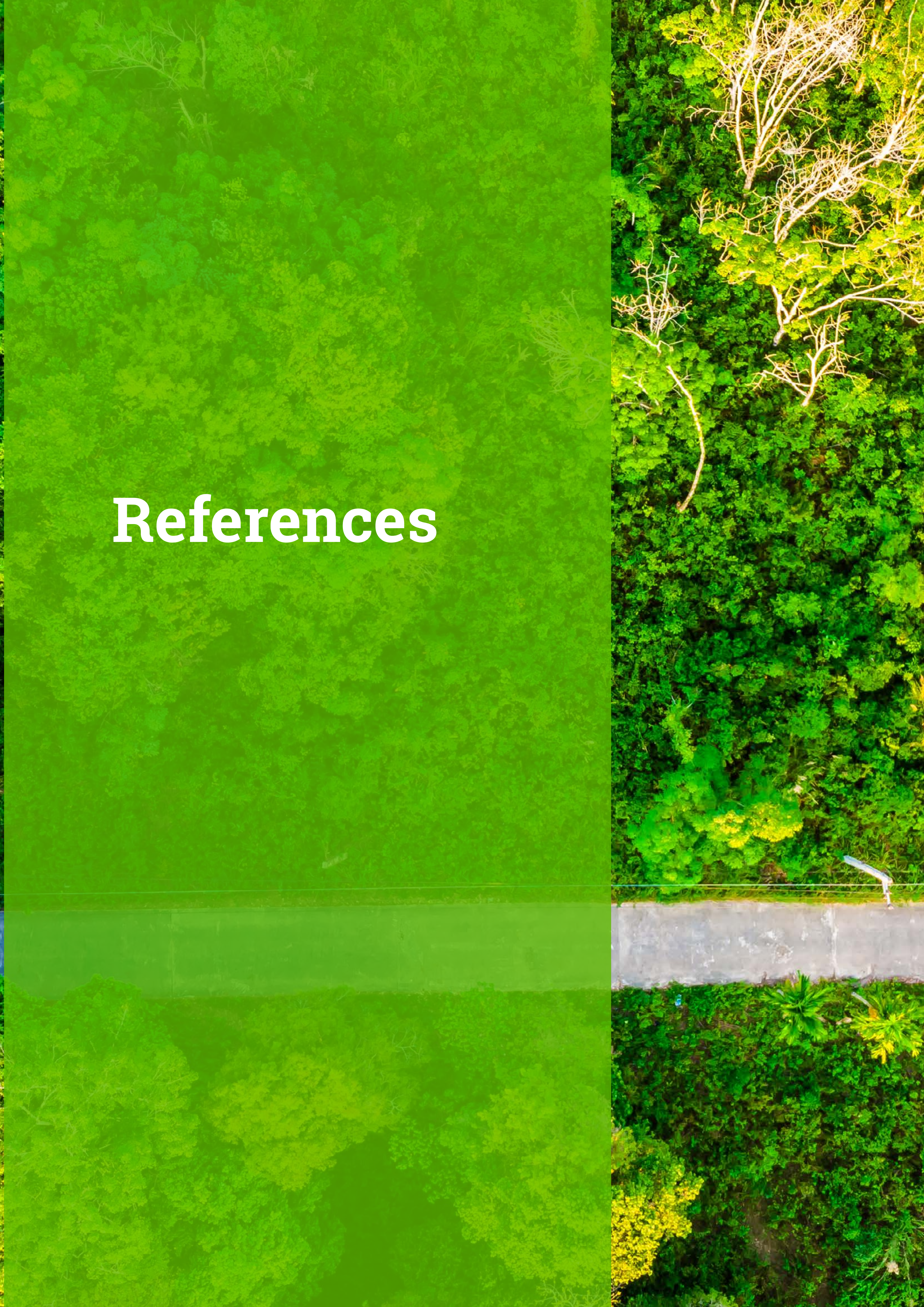

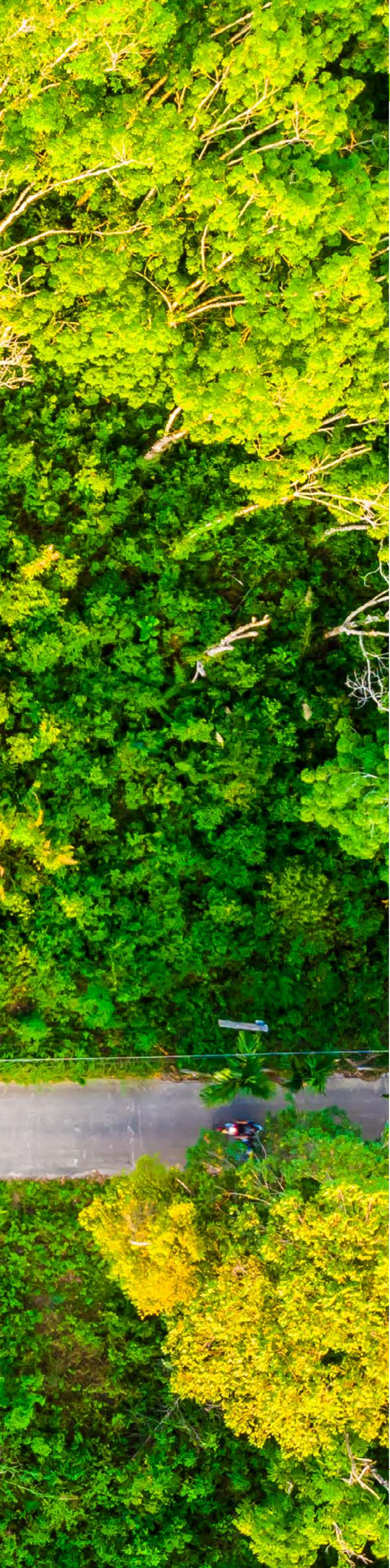

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