Transportation Research Part D 143 (2025) 104723

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Decarbonizing road transportation: Barriers and drivers in an emerging economy context

Minhazul Alam [a], A K M Rakib [b], A S M Monjurul Hasan [c,d,e,*], Md Nazrul Islam Siddique [f], Md. Ahsan Kabir [g], Andrea Trianni [c,e]

[a] Department of Mechanical Engineering, University of Michigan, Ann Arbor, MI 48109, United States
[b] Department of Electrical and Electronic Engineering, Islamic University of Technology, Gazipur 1704, Bangladesh
[c] School of Mechanical and Mechatronic Engineering, Faculty of Engineering and IT, University of Technology Sydney, 2007 Ultimo, NSW, Australia
[d] School of Professional Practice and Leadership, Faculty of Engineering and IT, University of Technology Sydney, 2007 Ultimo, NSW, Australia
[e] Centre for Advanced Manufacturing, University of Technology Sydney, NSW, Australia
[f] School of Engineering and Technology, University of New South Wales, Canberra ACT-2610, Australia
[g] Department of Electrical & Electronic Engineering, Military Institute of Science and Technology, Dhaka, Bangladesh

A R T I C L E I N F O

Keywords:
Decarbonization
Barriers
Drivers
Transportation
Sustainable transportation

A B S T R A C T

The transportation sector ranks as the second-largest contributor to global greenhouse gas emissions, primarily owing to its heavy reliance on fossil fuels. Consequently, the imperative to decarbonize transportation is paramount in the pursuit of sustainable development goals. However, despite its critical importance, research on decarbonization in transportation remains significantly limited. This gap in research is particularly glaring in developing countries, where there is a notable absence of studies addressing the decarbonization challenges within the transport sector. Addressing this research gap, this study aims to investigate the barriers and drivers influencing the decarbonization of the passenger transport sector in an emerging economy context, particularly for Bangladesh. The top three barriers identified include the 'Lack of concrete transportation policy', 'Lack of decarbonization strategy/policy', and 'Lack of biofuel refueling station/EV charging station'. These barriers are comprehensively analyzed based on various stakeholder perspectives. In terms of categorical barriers, policy barriers and technical barriers are predominant over other barriers. Despite these challenges, there is a growing interest in decarbonizing the transportation sector, albeit with some limitations. The primary drivers to decarbonize the transport sector include 'Profitable return on investment' and 'Government subsidies'. In terms of categorical drivers, economic drivers are dominant, followed by policy and social drivers. These findings are particularly relevant to the government bodies, users, manufacturers, and policymakers, offering valuable insights for navigating the complex landscape of decarbonizing passenger transport in emerging economies.

* Corresponding author at: School of Mechanical and Mechatronic Engineering, Faculty of Engineering and IT, University of Technology Sydney, 2007 Ultimo, NSW, Australia.

E-mail addresses: minhaz@umich.edu (M. Alam), rakib4@iut-dhaka.edu (A.K.M. Rakib), asmmonjurul.hasan@uts.edu.au (A.S.M.M. Hasan), md_nazrul_islam.siddique@unsw.edu.au (M.N.I. Siddique), ahsan@eece.mist.ac.bd (Md.A. Kabir), Andrea.Trianni@uts.edu.au (A. Trianni).

https://doi.org/10.1016/j.trd.2025.104723
Received 19 July 2024; Received in revised form 17 March 2025; Accepted 26 March 2025
Available online 11 April 2025
1361-9209/

1. Introduction

1.1. Background

The transport sector is a key contributor to global carbon emissions, with road transportation identified as the primary source, mainly due to the burning of fossil fuels like gasoline and diesel. This sector is responsible for a significant proportion of global energy consumption and CO_2 emissions. For instance, it accounted for 37 % of CO_2 emissions from end-use sectors in 2021 (Maestre et al., 2023). Thus, the International Energy Agency (IEA) mandates a 20 % emission reduction in transport by 2030 to align with the 2050 Net Zero goal (International Energy Agency, 2022).

Bangladesh, as an emerging economy, faces significant challenges in reducing CO_2 emissions, particularly from its road transportation sector (Hossain et al., 2021). By January 2024, the country had a total of 5,982,765 registered vehicles (Bangladesh Road Transport Authority, 2023), with over 80 % emitting excessive black smoke, primarily from petrol and diesel engines (Khuda, 2020). In fact, the transport sector contributed 9.92 % to Bangladesh's GHG emissions, expected to rise to 36.28 million metric tons by 2030, with road transport being the largest contributor (MOEF, 2021). In response, the country has committed to reducing GHG emissions in its transport sector by 3.39 million metric tons by 2030 unconditionally (MOEF, 2021). Therefore, the urgent transition towards road transportation decarbonization is essential to substantially reduce carbon emissions, leading to improved air quality, public health, and overall environmental sustainability (Lu et al., 2022; Panoutsou et al., 2021).

In the broader academic discussion on road transportation decarbonization, studies have predominantly focused on electrification. For instance, Wang et al. (2023) discussed the critical role of electric vehicles (EVs) in decarbonization, while Li et al. (2023) highlighted the importance of grid readiness and integrating renewable energy sources to support the transition. Additionally, Ehsani et al. (2021) examined how EV adoption aligns with broader decarbonization initiatives. Nonetheless, the studies have overlooked the barriers and drivers to decarbonization. In contrast, scholars have also emphasized the role of energy efficiency (EE) in vehicle design and operation, arguing that EE directly reduces the environmental footprint of transportation systems (Dorian & Fesharaki, 2019). However, to the best of the authors' knowledge, there is a notable gap in the literature regarding comprehensive discussions of the barriers that impede the adoption of decarbonization technologies in transportation, as well as the drivers that facilitate their implementation.

Similarly, studies have emphasized the potential of low-carbon fuels, including biofuels and renewable hydrogen, as critical components of transportation decarbonization strategies. In this domain, scientific literature quickly expanded on discussing the production of renewable fuels, highlighting different transportation including maritime transportation (Harahap et al., 2023), aviation, & haulage (Gray et al., 2021; Laguipo et al., 2022). Studies also looked at outlining roadmaps for alternative fuels, including the use of green ammonia (Balci et al., 2024). Interestingly, the life cycle perspective was also considered while arguing about low-carbon fuels (Tomos et al., 2024). However, these studies have largely neglected the road transport perspective with consideration of strategic pathways to effectively decarbonize the transportation sector. Interestingly, scholars have considered system-level opportunities, including the optimization of traffic flow through the deployment of advanced traffic management systems, the implementation of congestion mitigation strategies, the enhancement of supply chain efficiency through the application of route optimization algorithms, and the advocacy for the adoption of sustainable travel modes such as mass transit systems, cycling infrastructure development, and pedestrian-friendly urban planning (Chen & Jia, 2021; Tang et al., 2020). However, a few studies have addressed the barriers and drivers that influence the implementation and success of these system-level interventions.

Furthermore, researchers have investigated decarbonizing transportation on a regional basis. For example, Emodi et al. (2022) discussed decarbonization efforts in the Global South region, while Kinsella et al. (2023) focused on electrifying taxis in Ireland. Additionally, scholars have examined decarbonizing freight transport in various regions across Latin America (Cantarero, 2019; de Saxe et al., 2023), overall Europe (Danielis et al., 2022; Dyrhauge, 2021), Italy (Noussan et al., 2024) and Germany (Seibert et al., 2023) However, the majority of studies have primarily focused on large and developed economies, neglecting the specific challenges faced by emerging economies. In fact, there is a notable lack of research addressing the barriers and drivers to decarbonizing the road transportation sector in emerging economies.

1.2. Transportation system and policy framework in Bangladesh

The transportation infrastructure of Bangladesh is quite complicated with roads carrying over 80 % of national passenger traffic, The road transportation network, which carries over 80 % of the nation's passenger traffic, includes both public and private vehicles, though it remains poorly regulated (Ahmed et al., 2024; Raza & Lin, 2023). Country's road transport sector has expanded in the recent past, driven by increased demand for personal automobiles among the country's expanding middle class. The motorcycle is the common mode of transport for the middle class (Hossain & Gülen, 2007) accounting for approximately 70 % of Bangladesh's vehicle stock, with 3.58 million registered. Private passenger cars account for roughly 7.5 % (385,113), while pick-up trucks represent around 2.8 % (145,604). Buses constitute about 1 % (49,673), and auto-rickshaws stand at nearly 6 % (306,148). Other vehicles, including delivery vans, covered vans, and jeeps, fill the remaining percentages (Bangladesh Road Transport Authority, 2020). EVs in Bangladesh, comprising mainly of easy Bikes, auto-rickshaws, and electric motorcycles, face higher charging rates as business consumers and suffer from a lack of charging stations and grid pressure, prompting limited solar-based stations (Karmaker et al., 2020).

Bangladesh's transport system suffers from lack of coordination and overlapping policies. Efforts like the Strategic Transport Plan (STP) aimed to improve transit through projects like Mass Rapid Transit and Bus Rapid Transit, but lack of collaboration between authorities has resulted in cost overruns and enforcement gaps due to outdated regulations (Ahasan et al., 2023). Similarly, the

Table 1
Selected studies highlighting the decarbonization of transportation and related policies.

Authors and years	Country	Span of the study	Methodology	Study narration	Result	Remark
Victor Gallardo et al. (2024)	Costa Rica	2018–2050	Model based methods; calculations are performed by using yearly data.	Provides several policy implications which can help countries to reform tax structures that negate the fiscal impact of decarbonizing while fulfilling economic and environmental goals (Victor-Gallardo et al., 2024).	Highlights the risk of revenue losses; tax adjustment is argued in the policy to support decarbonization efforts.	Presents a fiscal strategy to sustain government revenues amid transport decarbonization, demonstrating that tax adjustments can offset losses while preserving economic benefits for firms and households.
Kim, Lim and Lee (2024)	Korea	2019	Adopts a comprehensive economic model; also incorporates a computable general equitable model for data analysis.	Looks into a wide range of policy options and provides important guidance for application (Kim et al., 2024).	Six policy scenarios are assessed: three policy mix scenarios under a national integrated computable general equilibrium model.	Emphasizing the need for stronger EV incentives, taxation, and ICEV bans to balance economic growth and emission reductions.
Dolge et al. (2023)	EU Countries and UK	2010–2019	Methodology consists of 3 parts; 15 indicators are used; decomposition analysis is carried out based on 5 factors.	Argues that individual transport policy for decarbonization would be a significant driver for EU member states (Dolge et al., 2023).	The study concludes that significant improvement can be made in European countries and the UK regarding making transportation more sustainable.	Highlights the uneven progress in transport decarbonization across European countries, emphasizing the need for tailored national policies alongside EU-level measures to achieve green deal targets.
Tsemek idi Tzeirana ki et al. (2023)	EU member countries	2000–2018	Data is analyzed based on the dataset by a decomposition analysis based on the Logarithmic Mean Divisia Index Technique.	Focuses on technology aspects and regional sustainability (social drivers); emphasis to "strengthen" the current policies to achieve long-term decarbonization goals; economic drivers are also discussed.(Tsemekidi Tzeiranaki et al., 2023)	Highlights the importance of strengthening the policy framework at the EU.	Underscores the persistent challenge of rising demand and the need for stronger policies to meet long-term climate targets.
Bu et al. (2021)	China	Up to 2050	The study uses the Chinese Provincial Passenger Transport Energy and CO_2 emissions model to analyze the data from 31 provinces to project the energy demand and CO_2 emissions of China's transportation sector.	Argues about a tailored policy approach integrating technical, social, and financial aspects as the key drivers for transport decarbonization (Bu et al., 2021).	The results show that emissions will be highest around 20,245 at 647 MtCO2 under the existing policies.	Shows that a mix of efficiency improvements, clean fuels, and public transport expansion can achieve net-zero emissions by 2050
Loo, Li and Namdeo (2023)	China, India	2009 – 2020	Utilizes different techniques including top-down, bottom-up and Activity-Modal Share-Energy Intensity-Carbon Intensity of Fuel (ASIF) approach.	Discussed methods regarding policy transformation for achieving decarbonization and poses several remarks with recommendations (Loo et al., 2023).	Policies are focused on technology issues promoting EVs, reducing transport demand, and shifting to low-carbon modes.	Advocates for a mix of EV adoption, demand reduction, modal shifts, and cleaner electricity to enhance climate policy effectiveness.
Das et al. (2021)	India	Post 2019	Survey methods is applied; data analysis is conducted using a logistic regression model.	Highlights that local context should be considered while developing policies; the role of policymakers is highlighted in the need to implement policies that revitalize public transportation and restore public confidence in its reliability (Das et al. 2021).	Technical drivers are highlighted to support decarbonization; market and social barriers are little articulated.	Highlights the pandemic-induced shift from public transport to private cars in India, emphasizing the need for policies that restore confidence in public transit through safety, hygiene, and improved service quality.

(*continued on next page*)

Table 1 (*continued*)

Authors and years	Country	Span of the study	Methodology	Study narration	Result	Remark
Lefèvre et al. (2021)	Japan, UK, Mexico and France	Up to 2050	A novel framework based on the Deep Decarbonization Pathway framework has been used in this paper to design and compare decarbonization pathways.	Technical and social drivers are highlighted; argues that social drivers also influence economic drivers (Lefèvre et al., 2021).	The paper provides suggestions through which strong decarbonization can be achieved. Other strategies are also suggested on a both local and national level in the mentioned countries.	Introduces a novel framework for designing long-term passenger transport decarbonization pathways, emphasizing the need for holistic, country-specific strategies.
da Silva et al., 2022	Brazil	2016 – 2050	The paper benchmarks the performance with the OSeMOSYS model.	Analyzed 48 mitigation strategies with respect to broader decarbonization (Silva et al., 2022).	Argues that a policy mix of technology and financial issues can significantly enhance the decarbonization process.	Summarizes that expanding shared mobility, biofuels, and public transport cuts emissions, while carbon pricing is effective but costly without strong transit growth.
Patil et al., 2024a; Patil et al., 2024b	Norway, China, USA, EU, and India.	–-	Qualitative analysis is applied.	Analyzes the different available decarbonization media and then suggests strategies and pathways towards decarbonization (Patil et al., 2024a).	Financial drivers are discussed; discusses that barriers mainly arise from cost and customer perspectives.	Highlights the crucial role of government policies, infrastructure, AI, and battery innovations in accelerating transport decarbonization.

National Integrated Multimodal Transport Policy of 2013 aims to create sustainable, connected transport networks, but inconsistent implementation, funding issues, and reliance on external investment have caused delays. The Automobile Industry Development Policy, 2021 provides incentives for EV assembly, manufacturing, and battery recycling but lacks a roadmap for carbon reduction and promotes EVs without sustainable charging infrastructure, limiting decarbonization (Ministry of Industries, 2024). Besides, the Electric Vehicle Registration & Operation Guideline – 2023 defines EV types and registration procedures but overlooks charging infrastructure readiness, including grid modification and battery infrastructure support (Bangladesh Road Transport Authority, 2024). The Nationally Determined Contributions of Bangladesh, 2021 sets emission reduction targets but lacks actionable strategies in particular funding mechanisms and infrastructure support, leaving the path to decarbonization unclear (MOEF, 2021). Furthermore, the Electric Vehicle Charging Guideline, 2022 focuses on safety standards but lacks a sustainable business model (DMTCL, 2022). Although the Mujib Climate Prosperity Plan: Decade 2030, 2021 calls for a 30 % EV fleet by 2030, it offers no specific plans for financing, infrastructure, or technology development, ignoring alternative sustainable forms of transportation and hindering a comprehensive decarbonization approach (Mujib Climate Prosperity Plan, 2022).

1.3. Research objective and contribution

Building on the initial background, this study aims to examine the barriers and drivers of road transportation decarbonization in Bangladesh. In this context, this study defines ’transportation decarbonization’ strictly in terms of technology-driven interventions, deliberately limiting the scope to various decarbonization technology options (Lefèvre et al., 2021; Meyer, 2020). While active travel and shared mobility are often highlighted in the broader discourse, we contend that their impact, while valuable, is insufficient to address the scale of emissions reductions needed in the current context (de Blas et al., 2020). Therefore, we excluded these concepts from the analysis to maintain a clear focus on technological solutions as the primary drivers of decarbonization (Speizer et al., 2024).

The novelty of this work lies in its focused examination of the specific barriers and drivers to decarbonizing the transportation sector in Bangladesh. In fact, focusing on road transportation in Bangladesh is crucial because it is the primary mode of transport for people and goods, playing a vital role in economic growth, regional connectivity, and social integration (Bangladesh Road Transport Authority, 2023). While existing studies have primarily focused on decarbonization efforts at large, this study addresses a significant research gap by exploring the unique challenges and opportunities for an emerging economy’s context. Additionally, we have also highlighted suggestions to decarbonize the transportation sector, considering all stakeholders connected to the transport sector. This research holds utmost significance for academicians and policymakers working in the decarbonization field, offering valuable insights to inform policy decisions and strategies aimed at promoting sustainable transportation practices. Moreover, our findings can be beneficial to other emerging countries seeking to decarbonize their own transport sectors, providing a basis for further exploration and implementation of similar approaches.

The study is structured as follows: Section 2 highlights the literature background, followed by the research methodology in Section 3. Sections 4 and 5 analyze barriers and drivers with different statistical techniques. The discussion and policy implications are presented in Section 6, followed by the concluding remark and future research directions in Section 7.

Table 2
Selected studies discussing barriers and drivers to road transport decarbonization.

Authors and years	Country	Span of Study	Methodology	Study narration	Result	Remark
Kuo et al. (2022)	Taiwan	–-	The study uses the decision-making trial and evaluation laboratory (DEMATEL) and an analytical network process (ANP) method to analyze barriers to decarbonization from an automotive perspective.	Barriers related to EV diffusion analyzed; relationship between barriers and drivers; links between barriers to EV adoption are discussed (Kuo et al., 2022).	Most prominent barrier found to be battery capacity and lifespan; charging time is also a significant barrier.	Focused on EV, little discussion on other decarbonization pathways.
Zailani et al. (2019)	Malaysia	–-	Survey technique; incorporates 147 transportation companies in Malaysia and analyzed the data using a partial lease square technique.	Identifies and ranks the barriers to decarbonization efforts and suggests areas where policymakers can focus to tackle the barriers (Zailani et al. 2019).	Lack of government support, benefits and competitiveness are identified as significant barriers.	Study solely works with response from transportation companies and excludes other users of biodiesel; does not address internal barriers.
Adamashvili and Thrassou (2024)	India, USA, Australia, Malaysia and Canada	2015–2024	Review methodology using a Systematic Literature Review (SLR).	Highlights challenges and potential solutions associated with EV adoption and infrastructure deployment (Adamashvili and Thrassou 2024).	Highlights drivers such as subsidies, tax incentives for greater EV adoptions	Focused on EVs; other decarbonization technologies are little discussed.
Santarromana, et al. (2020)	France, Germany, Italy, Netherlands, Norway, Spain and Portugal	2017	Methodology involves a pair-wise comparison using market data.	Identifies the importance of monetary incentives for decarbonization; proposes a surcharge model coupling EV charging with carbon intensity (Santarromana et al., 2020)	Shows that fiscal incentives significantly boost EV adoption.	Focuses on the economic aspects of decarbonizing the transport sector.
Biresselioglu et al. (2018)	Turkey	2003—2017	Comprehensive review methodology.	Argues that there is insufficient investigation into formal and collective decision-making levels; also highlights that barriers outweigh drivers, urging coordinated policy efforts, transparent information, and enhanced incentives to boost EV market acceptance (Biresselioglu et al., 2018).	The lack of charging infrastructure is identified as the most significant barrier; environmental aspect is the most important driver.	Categorical analysis of drivers and barriers based on grouping.
Noussan et al. (2024)	Italy	–-	Evaluating the supply chain of biomethane production.	Argues that biomethane is a viable decarbonization option; economic aspect of biofuel implementation addressed (Noussan et al. 2024).	Highlights the environmental benefits as a driver to biofuel adaptation.	Limited discussion around other decarbonization technologies including EV, energy efficiency etc.
Hewitt (2024)	Ireland	–-	Employs a system-wide energy planning framework of decarbonization technologies.	Nine decarbonization sources are addressed; discusses a city-wide decarbonization strategy; proposes an	Lack of systemwide thinking is identified as one of the critical barriers; integrated use of renewable fuel,	Lack of holistic consideration of barriers and drivers.

(continued on next page)

Table 2 (*continued*)

Authors and years	Country	Span of Study	Methodology	Study narration	Result	Remark
				economic analysis of the prospects of decarbonization steps (Hewitt 2024).	energy efficiency, electrification, and hydrogen technologies are required for successful decarbonization.	
Khatiwada et al. (2022)	Portugal	2020, 2030, and 2050.	Techno-economic analysis; levelized cost analysis; SWOT-PEST analysis, and expert elicitation.	Develops a framework supporting carbon–neutral economy (Khatiwada, Vasudevan, and Santos 2022).	Identifies cost, regulations, institutions, perception and constraints in creating market demand as key barriers.	Drivers are little considered; other low carbon fuels are not discussed.
Noel et al. (2020)	Iceland, Sweden, Denmark, Finland and Norway	2016—–2017	Semi-structured interviews with 227 stakeholders, analyzed through grounded theory and cluster analysis, supported by a literature review.	Identifies a total of 53 barriers in the Nordic region; identifies range anxiety as a substantial barrier (Noel et al. 2020).	Consumer knowledge and experience is the main cause of technical barriers; highlights sociotechnical factors for EV adoption.	Lack of comprehensive focus on drivers.
Kim et al. (2024)	South Korea	2019	Integrated computable general equilibrium (CGE) model combined with a vehicle stock dynamics module.	Environmental rebound effects are discussed; drivers to EVs are discussed; financial drivers are highlighted including subsidies (Kim, Lim, and Lee 2024).	Financial and policy drivers are highlighted; economic subsidies are discussed.	Barriers are generally considered, overlooking broader categorization of barriers.
Pyra (2023)	Poland	2025, 2030, and 2035	Adopts the Generalized Reduced Gradient (GRG) method to perform non-linear optimization.	Discusses techniques and assessment of alternate technologies (Pyra 2023).	Focuses on the drivers, such as strict EU climate rules, developments in electric cars, and financial incentives, while pointing out barriers like budgetary limits, poor infrastructure, and dependency on developing technology.	Barriers and drivers are inadequately considered.
Cantarella et al. (2023)	Brazil, United States, Indonesia	–-	Case study approach.	Argues that policies and innovation are needed to address decarbonization highlights biofuels as a major focus for decarbonization (Cantarella et al., 2023).	Identifies drivers such as policy support, feedstock utilization, economic contributions, and barriers such as market fluctuations, technological gaps, cost, and scale in the context of biofuel technologies.	Too focused on biofuel, inadequate attention to the other decarbonization technologies.
Nakorji et al. (2023)	Nigeria	2000–2017	Adopts reviews approach incorporating historical data on fuel consumption, greenhouse gas (GHG) emissions, and policy frameworks.	Advocates short-term biofuel-based mass transportation options, long-term adoption of EV, and supportive policies to achieve decarbonization targets (Nakorji et al., 2023).	Highlights drivers such as policy commitments, infrastructure development; major barriers are dependence on fossil fuels, high costs, and behavioral and cultural challenges.	Inadequate consideration of barriers and drivers.
Gonçalves et al. (2022)	Brazil	2023–2031	Employs a stakeholder-oriented approach involving literature reviews, structured interviews, and semi-structured interviews.	Discusses decarbonization pathways; emphasizes the importance of policy frameworks (Gonçalves et al., 2022).	Electric mobility is highlighted to support decarbonization; abundant biofuel resources, and opportunities in infrastructure development are identified as key drivers.	Barriers are little discussed.

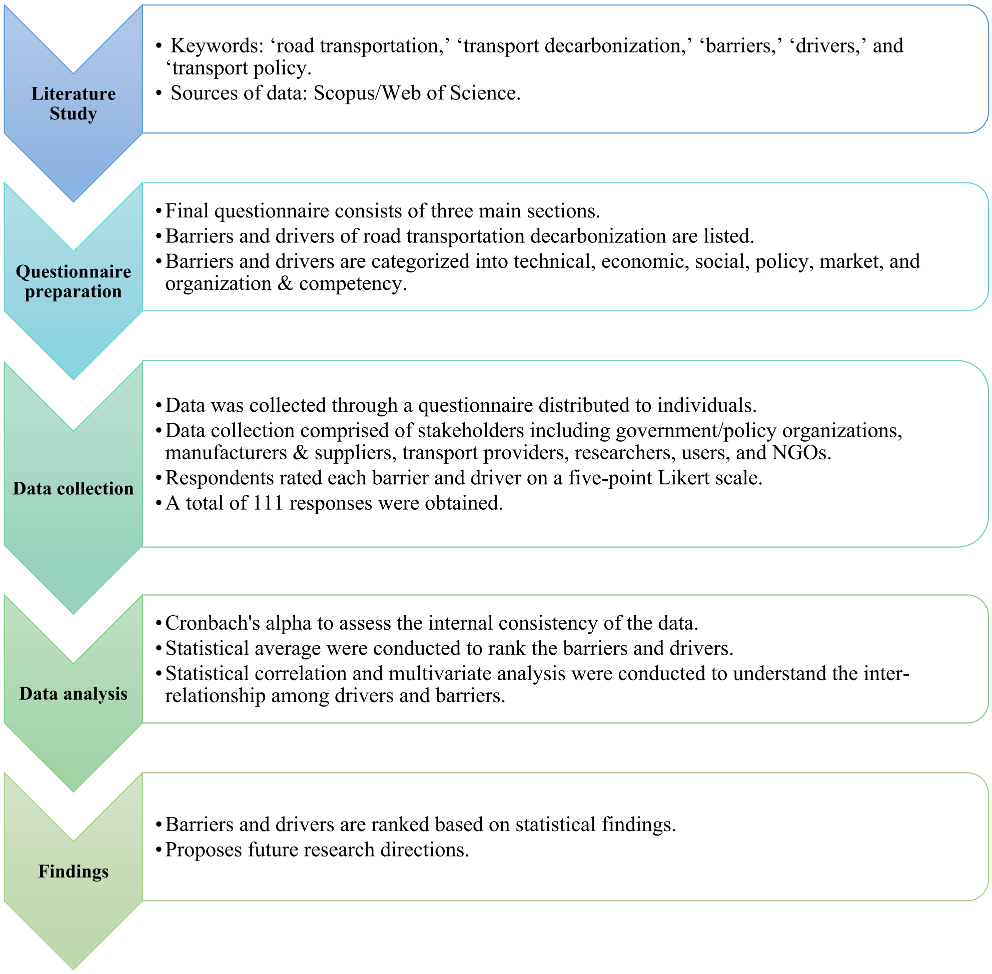

Fig. 1. Flow structure of the research.

2. Literature background

This section presents the transportation system & policy framework in Bangladesh, relevant policy frameworks in different countries that support transportation decarbonization initiatives, and relevant studies on barriers and drivers to transport decarbonization.

2.1. Policy frameworks in decarbonizing transportation

Decarbonizing the road transport sector requires well-planned public policies, though the sequencing of actions is often unclear, particularly in countries like Bangladesh. Academic studies have highlighted the policy discourse considering geographic, economic, socio-cultural, and environmental factors. For instance, the importance of technical assistance, fiscal strategies, and regional sustainability are discussed in decarbonization efforts. Simultaneously, scholars also argued that policies tailored to local contexts can effectively drive both decarbonization and economic growth. Furthermore, scholars highlighted social drivers in the policy mechanism to support transportation decarbonization actions. Table 1 provides a summary of the selected studies highlighting transportation decarbonization and relevant policies.

2.2. Barriers and drivers to road transportation decarbonization

The ongoing discussion on barriers to transport decarbonization often centers on specific technologies rather than embracing a comprehensive decarbonization perspective. For instance, Krishna (2021) analyzed barriers to EV adoption through thematic analysis. Similarly, Adhikari et al. (2020) and H. Zhang et al. (2024) prioritized the barriers to EVs, categorizing barriers into technical, policy, economic, infrastructure, and social. On the contrary, Panoutsou et al. (2021) examined barriers to biofuel adoption in European countries only. Barriers to energy efficiency in the transport sector are also analyzed, however, overlooking the policy implication and

Table 3
Barriers to decarbonizing the road transportation.

Categories	Notation	Barriers	Remark	Reference
Technical	B1	Lack of biofuel refuel station/ EV charging station	Absence or scarcity of facilities necessary for refueling biofuel or recharging EV.	(Egbue & Long, 2012; Tarei et al., 2021)
	B2	Lack of technical experts	Shortage of professionals with the necessary skills and knowledge for implementing and maintaining decarbonization technologies.	(Lefèvre et al., 2021; Silva et al., 2022)
	B3	Un-availability of proven technology	Limited access to established, reliable, and effective technologies suitable for decarbonization in the transportation sector.	(Rapson & Muehlegger, 2023)
	B4	Poor quality services	Inefficient infrastructure and unreliable options that hinder the shift to low-carbon solutions.	(Egbue & Long, 2012)
	B5	Planning and installation issues	Challenges in designing and implementing infrastructure.	(Tarei et al., 2021)
Economic	B6	Uncertain return on investment	Financial risks associated with decarbonization investments due to unpredictable market conditions.	(Nagaj et al., 2024)
	B7	Lack of financing opportunities	Limited access to funds tailored for decarbonization initiatives.	(Rapson & Muehlegger, 2023)
	B8	Uncertainties of receiving financial support	lack of assurance regarding the availability or consistency of funding for decarbonization projects.	(Victor-Gallardo et al., 2024a)
	B9	High initial investment	Large upfront capital for implementing decarbonization technologies or infrastructure.	(Gillingham & Sweeney, 2012; Tarei et al., 2021)
	B10	Uncertain development and operational costs	Unpredictable expenses related to the establishment and maintenance of decarbonization technologies.	(Axsen et al., 2018; Bu et al., 2021)
	B11	Lack of investment incentives	Inadequate financial programs encouraging investment in transport decarbonization.	(Rapson & Muehlegger, 2023)
	B12	High cost for end users	Elevated expenses incurred by consumers when adopting low-carbon transportation options.	(Egbue & Long, 2012)
	B13	Hidden cost	Unforeseen or indirect expenses associated with the implementation of decarbonization measures.	(Gillingham & Sweeney, 2012)
Social	B14	Perceived negative impacts	Public concern over potential drawbacks of decarbonization efforts.	(Egbue & Long, 2012)
	B15	Lack of sufficient knowledge	Inadequate understanding about decarbonization technologies and benefits.	(Egbue & Long, 2012; Gillingham & Sweeney, 2012; Tarei et al., 2021)
	B16	Lack of awareness about the policies, technology and its benefits	Inadequate knowledge of decarbonization policies and the potential advantages of adopting clean technologies.	(Victor-Gallardo et al., 2024)
	B17	Political unwillingness	Lack of support or proactive measures from policymakers to drive decarbonization initiatives.	(Godínez-Zamora et al., 2020; Victor-Gallardo et al., 2024)
	B18	Resistance to change	Hesitancy among stakeholders/consumers to transition from traditional practices to low-carbon alternatives.	(Egbue & Long, 2012; Gillingham & Sweeney, 2012)
	B19	Socio-economic differences between major cities and regional areas	Disparities in the capacity to adopt decarbonization strategies between urban and rural areas.	(Patil et al., 2024)
Policy	B20	Unclear and complex legislative issues	Complicated rules & regulations that hinder decarbonization efforts.	(Gautam et al., 2017)
	B21	Lack of financial policy	Absence of economic regulations or policies that support decarbonization investments.	(Gillingham & Sweeney, 2012; Tarei et al., 2021)
	B22	Insufficient attention from government	Lack of focus or priority on decarbonization within governmental agendas.	(Tarei et al., 2021)
	B23	Bureaucratic complexity	Complex administrative processes that delay or complicate decarbonization efforts.	(Gillingham & Sweeney, 2012)
	B24	Lack of concrete transportation policy	Absence of a comprehensive, clear policy framework for sustainable transportation.	(Gray et al., 2021)
	B25	Lack of decarbonization strategy/policy	Inadequate strategy or policy dedicated to achieving low-carbon transportation.	(Loo et al., 2023)
Market	B26	Immature automobile market	Underdeveloped market with limited availability of advanced or sustainable vehicles and inadequate supporting automobile infrastructure.	(Pan et al., 2018)
	B27	Unsettled fuel market	Instability in fuel markets, affecting the supply and demand for alternative fuel sources.	(Pan et al., 2018)
	B28	Low demand from customer	Insufficient consumer interest for low-carbon vehicles or technologies.	(Loo et al., 2023)
	B29	Lack of participation in global carbon market	Limited involvement in international carbon trading or market mechanisms.	(Khan & Aziz, 2022)

(*continued on next page*)

Table 3 (*continued*)

Categories	Notation	Barriers	Remark	Reference
	B30	Lack of private support	Minimal engagement or investment from the private sector in decarbonization efforts.	(Verlinghieri et al., 2024)
	B31	Lack of user experience	Limited practical experience in implementing decarbonization measures.	(Tarei et al., 2021)
	B32	Competition with fossil fuels	Challenge of clean transportation options competing against well-established fossil fuel-based systems.	(Axsen et al., 2018)
Organization & competency	B33	Lack of services	Insufficient support services for the adoption and maintenance of low-carbon transportation technologies.	(Hafner et al., 2017)
	B34	Poor research & development	Inadequate progress in research & development to decarbonization technologies and practices for road transportation.	(Lathia & Dadhaniya, 2019)
	B35	No unique platform for stakeholders	Lack of a centralized or collaborative platform for stakeholders involved in transportation decarbonization.	(Trianni et al., 2017)
	B36	Lack of decarbonization activities experience	Limited experience in implementing decarbonization actions within organizations.	(Meyer, 2020)
	B37	Lack of co-ordination in decarbonization projects	Poor collaboration among stakeholders about decarbonization efforts.	(Trianni et al., 2017)

market dynamics (Dorian & Fesharaki, 2019). Additionally, studies also investigated barriers to distinct sustainable pathways for decarbonizing transportation covering different geographical area, including China (L. Zhang & Bai, 2021), New Zealand (Imran & Pearce, 2015), Australia (Gleeson et al., 2003), and Sweden (Pettersson et al., 2022). However, these studies often lack integration into a unified framework addressing systemic decarbonization challenges in transportation.

Whilst it comes to drivers for transport decarbonization, literature has identified few of them, although categorizing the drivers very generically or discussing the drivers for individual decarbonization pathways for transportation. For example, Haddadian et al. (2015) focused on the policy framework and its' implication in EVs. Matheus et al. (2024) highlighted financial motivation towards biofuel use in transportation. Similarly, social drivers are also discussed supporting transport decarbonization (Gasparatos et al., 2015). Market drivers, alongside organizational issues, have been discussed in academic debates (Feng & Wang, 2018). However, there is a significant lack of research that thoroughly examines the factors driving transport decarbonization. While some scholars have highlighted drivers, these discussions are often limited to specific technologies such as EVs or biofuels for transportation. Table 2 provides an overview of selected studies addressing the barriers and drivers of road transport decarbonization.

Upon reviewing existing studies, it becomes evident that much of the scholarly work on transportation decarbonization remains superficial, with a predominant focus on limited consideration of barriers and drivers. Besides, the studies often concentrate on specific technologies (e.g. EV, biofuel), failing to account for the broader, systemic dimensions of decarbonization. Additionally, there is a notable gap in the literature concerning a detailed, multidimensional examination of the specific barriers and drivers to road transport decarbonization. Such an analysis must go beyond technical factors to include social, economic, and market dynamics. Therefore, further research is needed to identify the multi-dimensional (e.g. technical, social, economic, market) challenges that hinder the widespread adoption of these technologies, as well as the factors that can drive their successful implementation.

3. Methodology

This study utilized a quantitative analytical framework, following the approach outlined by Brenner (2020), Gable (1994) and Nardi (2018), to systematically examine the drivers and barriers associated with the decarbonization of road transportation in Bangladesh. The methodological approach aligns with practices in the broader field of decarbonization research, underscoring its applicability for investigating multifaceted and context-specific challenges (Di Foggia, 2021; Globisch et al., 2018; Hasan et al., 2022; Ohene et al., 2023).

The study began with a literature review, which informed the initial development of a questionnaire, with questions carefully designed based on the insights from the existing body of literature. Besides, the questions were subsequently assessed by experts in transportation decarbonization to ensure they accurately captured the relevant issues. Data was then collected through a structured survey (Jones et al., 2015) with the developed questionnaire, targeting relevant stakeholders within the transportation sector. Following data collection, statistical methods were applied to analyze the data, allowing for identifying the critical barriers & drivers. Finally, the findings were presented, highlighting the most critical barriers and drivers that can influence the path toward sustainable and low-carbon road transportation in Bangladesh. Fig. 1 shows the methodological steps adopted in this research.

3.1. Literature study

A comprehensive literature review was carried out to explore decarbonization technologies in the transportation sector, assess the current state of the industry in Bangladesh, and identify the barriers and drivers of road transportation decarbonization efforts. In searching the literature, the key search terms included 'road transportation, 'transport decarbonization,' barriers,' 'drivers,' and 'transport policy.' The search criteria encompassed all types of publications indexed in Scopus and Web of Science, ensuring a thorough

Table 4
Drivers to decarbonizing the road transportation.

Categories	Notation	Drivers	Remark	Reference
Technical	D1	Efficient way of fuel utilization	Optimized and cost-effective use of fuel resources to minimize waste and emissions.	(A. Zhang et al. 2022)
	D2	Availability of technical experts/ services	Presence of a skilled workforce and service providers to support the adoption of low carbon transport solutions.	(Guno, Collera, and Agaton 2021)
	D3	Smart mobility solutions	Adoption of advanced transportation systems that enhance mobility efficiency and reduce carbon footprint.	(Haddadian, Khodayar, and Shahidehpour 2015)
Economic	D4	Profitable return on investment	Assurance of financial gains from investments in decarbonization technology or solutions.	(Jenn, Springel, and Gopal 2018; Muzir et al. 2022)
	D5	Availability of financial support	Existence of funding opportunities to facilitate investment in decarbonization efforts.	(Perissi & Jones, 2022; Trianni et al., 2017)
	D6	Incentive/subsidy scheme	Programs that provide financial benefits to encourage decarbonization investments.	(Khurshid et al., 2023b)
	D7	Loan at low interest rates	Financial package with low interest rates to support decarbonization projects.	(Khurshid et al., 2023b; Steenberghen & López, 2008)
	D8	Carbon tax/ Tax exemption	Tax policies aimed at either penalizing carbon emissions or offering tax relief for adopting low carbon solutions.	(Pettersson et al., 2022; Qiu et al., 2020)
	D9	Governments' subsidies	Financial support from the government to lower the cost burden for decarbonization projects.	(Haddadian et al., 2015; Qiu et al., 2020)
Social	D10	Possible Reduction in carbon emissions	Benefits of reducing carbon emissions for environmental sustainability.	(Gray et al., 2021; Yu et al., 2021)
	D11	Other environmental benefits (other than carbon dioxide reduction)	Advantages beyond carbon reduction.	(Noussan et al. 2024; Noussan, Hafner, and Tagliapietra 2020)
	D12	Attractiveness of diverse automobile market	Appeal of a market offering a variety of sustainable transport vehicle options.	(Gleeson, Curtis, and Low 2003; Imran and Pearce 2015)
	D13	Increased interest from end-user	Growing demand from consumers for cleaner and more efficient transportation options.	(Henriksen et al., 2021)
	D14	Political willingness towards Sustainable Development Goals (SDG)	Government support and alignment with SDGs for sustainable transport.	(Kuo et al. 2022; Panoutsou et al. 2021)
	D15	High quality public transport infrastructure	Well-developed public transportation systems that support decarbonization goals.	(Boulmrharj, Bakhouya, and Khaidar 2023)
	D16	Pressure posed by NGOs and clients	Influence from non-governmental organizations and consumers pushing for sustainable practices.	(Santos, Behrendt, and Teytelboym 2010)
	D17	Implementation of sustainable transportation systems	The development and execution of transportation systems designed to be environmentally friendly.	(M. R. Ahmed and Karmaker 2019; Karmaker et al. 2018)
Policy	D18	Meeting governmental SDG target	Achieving policy objectives related to sustainable development goals.	(Meckling et al., 2017; Santos 2017)
	D19	Adaptation to climate change	The need to reduce emissions and shift to sustainable transport to mitigate the impacts of climate change.	(Kuo et al. 2022; Panoutsou et al. 2021)
	D20	Specific target for carbon reduction	Clearly defined goals for reducing carbon emissions within the transportation sector.	(Biresselioglu, Demirbag Kaplan, and Yilmaz 2018)
	D21	Regulatory frameworks and emissions standards	Established regulations guiding emissions reductions and promoting cleaner transportation options.	(Shah et al. 2021; Steenberghen and López 2008)
Market	D22	Market diversification/opportunity	The potential for growth and diversification in the low emission vehicle market.	(M. R. Ahmed & Karmaker, 2019; Mohammadi & Saif, 2023)
	D23	Fuel use versatility	Flexibility and adaptability of fuel use allowing greater flexibility in fuel usage.	(Egbue and Long 2012; Nikolakakis et al. 2023)
	D24	Risk posed by increasing fossil fuel price	Opportunities arising from higher fossil fuel prices that can drive the adoption of cleaner alternatives.	(Nikolakakis et al. 2023; Qiu et al. 2020)
Organization & competency	D25	Environmental certification	Recognition for organizations or products that meet specific environmental standards.	(Asadi et al. 2022; C, A, and C 2019).
	D26	People with real ambition towards environmentally friendly technologies/services	Individuals or groups actively supporting and promoting decarbonization technologies.	(Santos, Behrendt, and Teytelboym 2010)
	D27	Environmental image	The positive perception of organizations or services that contribute to environmentally friendly practices.	(Ahasan et al. 2023)
	D28	Long term energy/environmental strategy	Development and commitment to a comprehensive long-term plan for sustainable energy use and environmental protection.	(Nikolakakis et al. 2023)

Table 5
Selected stakeholders for the investigation.

Stakeholders	Remark
Government/Policy organizations	Refers to governmental bodies responsible for developing, implementing, and regulating policies and regulations related to transportation.
Manufacturer & supplier	Companies involved in vehicle production, component manufacturing, and related supply chain activities.
Transportation Providers	Refers to entities involved in offering transportation services, such as logistics companies, public transit agencies, and private transportation operators.
Users	Refers to individuals (passengers) that utilize transportation services
Research institutions and academia	Refer to universities, colleges, and other educational institutions, as well as research organizations and professionals involved in transportation-related studies, research, and academic activities.
Non-Government Organizations (NGOs)	Independent entities advocate sustainable transportation practices.

and academically rigorous selection process. In total, 150 scientific papers and 12 practical case studies were reviewed, providing a well-rounded foundation of both theoretical and practical insights for this research project.

3.2. Questionnaire preparation

Whilst there are very limited studies that intrinsically examine the drivers and barriers to road transportation decarbonization, this research adopted a broader lens to identify and analyze these factors comprehensively. To design this study, existing research related to transportation decarbonization was strategically selected to provide a foundational understanding of the key barriers and drivers. While studies (Bullock et al., 2023; Ghaforian Masodzadeh et al., 2022; Rayner, 2021; Verlinghieri et al., 2024) focus on specific modes, such as road and shipping decarbonization, their findings extend beyond these modes and contribute meaningfully to the broader academic discourse on transportation decarbonization. However, while deriving the comprehensive list of individual barriers (see Table 3) and drivers (see Table 4), this study incorporated a wider array of literature to ensure a more holistic and contextually relevant perspective.

Furthermore, the research team went beyond a literature-based approach and conducted a collaborative review of the list of drivers and barriers with researchers, policy experts, and industry practitioners. This review process is deemed essential to ensure that the questionnaire captures the full spectrum of context-specific barriers and drivers. By actively engaging with stakeholders who are intimately familiar with Bangladesh's transportation sector, the research team ensured that the tool was not only theoretically sound, but also rigorously aligned with the practical realities and challenges of the local contexts (Cairns-Lee et al., 2021).

The questionnaire (see the 'supplementary material A') was structured into three main sections, each designed to capture specific insights systematically. The first section gathered detailed participant information, including occupation, role, and areas of expertise or focus within transportation decarbonization activities. The second section focused on evaluating barriers to transportation decarbonization. Barriers were classified into six comprehensive categories: technological, economic, social (including awareness and behavioral aspects), policy-related, market-based, and organizational/competence-related challenges. The third section explored the key drivers enabling decarbonization efforts. Like the barriers, drivers were categorized into six domains to ensure alignment and comparability. Finally, an open-ended section was included for additional comments or suggestions, providing participants with the opportunity to share insights beyond the structured questions. This section aimed to capture diverse perspectives and potential nuances not addressed in the predefined categories.

3.3. Data collection

In this phase, data was collected using a structured survey questionnaire administered to carefully selected participants. The use of a survey questionnaire in the study facilitated an in-depth quantitative assessment, offering respondents the flexibility to complete the survey at their own pace and convenience. This approach also helped minimize potential biases that can arise from the presence of a researcher, as is often the case with interviews, ensuring a more objective and reliable data collection process (Brant et al., 2015; Jones et al., 2015).

Six distinct stakeholders were contacted to take part in this research to ensure a comprehensive and multi-dimensional analysis of the barriers and drivers. These groups included representatives from government and policy organizations, manufacturers and suppliers, transport providers, researchers, users, and NGOs. Table 5 details the description of the survey participants, illustrating the diverse perspectives captured in the study.

The scope of this study was to gather insights from individuals possessing substantial knowledge on the subject matter. Therefore, the study intentionally excluded the perceptions of the general population. Instead, the selection of survey participants was purposeful, prioritizing professionals with at least 10 years of experience in the transportation sector and expertise in decarbonization technologies. This criterion was critical to ensuring the depth, reliability, and strategic value of the insights gathered. Professionals with over a decade of experience possess refined analytical skills and a comprehensive understanding of sector trends, enabling them to critically assess past developments, current practices, and future challenges. Research underscores the value of this approach, demonstrating that professionals with prolonged industry exposure develop superior decision-making and problem-solving abilities, rooted in their ability to critically analyse complex systems and foresee challenges (Ericsson, 2006). Moreover, experienced individuals are better

Table 6
Socio-demographic characteristics of the interviewees.

Category	Number of Respondents	Education Level	Occupational Role	Years of Experience	Specific Focus in Transportation Decarbonization	Technology Familiarity	Previous engagement in decarbonization Projects
Government/Policy Organizations	10	Bachelor's/ Master's	Assistant director; Director.	11 + years	Developing policies for EV adoption, carbon pricing, biofuel for transportation.	Medium-High (EV policies, low carbon fuel management)	EV incentives and infrastructure development
Manufacturers and Suppliers	36	Bachelor's/ Master's	Deputy Managers; Managers; Senior Managers	12 + years	Designing low-emission vehicles	High (EVs, biofuel)	EV design, green manufacturing processes
Transport Providers	17	Bachelor's	Managers, Operations Heads	10 + years	Managing fleets, optimizing routes for emissions reduction	Medium (Fleet electrification)	Fleet implementation
Users	27	Diploma/ Bachelor's	Vehicle Owners, Community Leaders	10 + years	EV adoption, user behaviour, and affordability issues	Low-Medium (Basic EV awareness)	Consumer trials of EVs
Research Institutions and Academia	16	Master's/PhD	Researchers, Professors	10 + years	Lifecycle emissions analysis, alternative fuels research	High (Lifecycle assessment tools, fuel analysis)	Analysis of lifecycle emissions, fuel studies
NGOs	5	Bachelor's/ Master's	Program Coordinators, Advocates	10 + years	Promoting sustainable mobility, equity in decarbonization	Medium (Awareness campaigns)	Equity-focused awareness campaigns

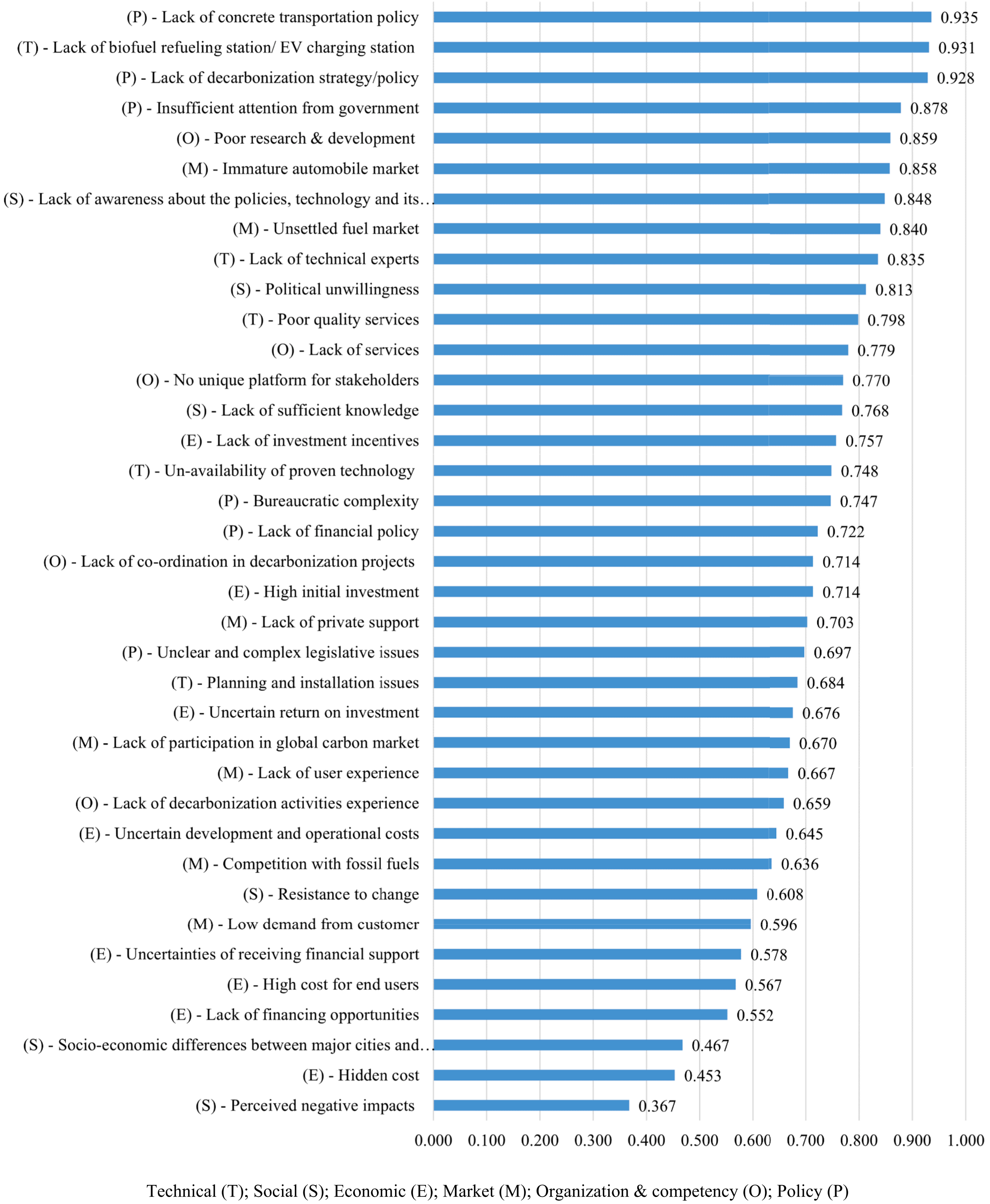

Fig. 2. Analysis of barriers by average for the whole sample. Technical (T); Social (S); Economic (E); Market (M); Organization & competency (O); Policy (P).

equipped to provide nuanced, actionable feedback, minimizing the risk of superficial responses (Kruger & Dunning, 1999). By focusing on this group, the study ensures data quality and credibility, drawing on the expertise of those most qualified to address the complexities of transportation decarbonization. Table 6 provides socio-demographic characteristics of the interviewees.

Data collection took place over an extended period, from January 2023 to August 2023. Data was collected by email, with initial

Table 7
Statical correlation analysis among the barriers. Values higher than 0.850 are marked.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32	B33	B34	B35	B36	B37
B1	1.00																																				
B2	0.32	1.00																																			
B3	0.26	0.61	1.00																																		
B4	0.06	0.66	0.71	1.00																																	
B5	0.22	0.19	0.62	0.43	1.00																																
B6	0.25	0.22	0.51	0.48	0.79	1.00																															
B7	0.16	0.23	0.49	0.39	0.15	0.40	1.00																														
B8	0.08	0.51	0.71	0.54	0.39	0.48	0.84	1.00																													
B9	0.46	0.21	0.39	0.12	0.38	0.06	0.52	0.21	1.00																												
B10	0.51	0.32	0.38	0.65	0.51	0.57	0.54	0.66	0.37	1.00																											
B11	0.30	0.35	0.07	0.41	0.16	0.11	0.06	0.18	0.03	0.01	1.00																										
B12	0.17	0.13	0.06	0.07	0.24	0.03	0.67	0.46	0.78	0.38	0.10	1.00																									
B13	0.20	0.39	0.47	0.39	0.17	0.25	0.76	0.79	0.43	0.60	0.27	0.64	1.00																								
B14	0.38	0.20	0.10	0.01	0.25	0.26	0.02	0.22	0.07	0.16	0.33	0.10	0.34	1.00																							
B15	0.35	0.63	0.81	0.63	0.24	0.42	0.62	0.69	0.13	0.23	0.27	0.08	0.48	0.08	1.00																						
B16	0.02	0.01	0.25	0.23	0.52	0.17	0.10	0.19	0.48	0.08	0.65	0.38	0.05	0.47	0.03	1.00																					
B17	0.52	0.20	0.08	0.16	0.54	0.48	0.05	0.03	0.19	0.36	0.19	0.34	0.20	0.15	0.11	0.27	1.00																				
B18	0.28	0.55	0.66	0.50	0.16	0.45	0.68	0.67	0.03	0.17	0.25	0.14	0.45	0.11	0.93	0.01	0.07	1.00																			
B19	0.00	0.36	0.33	0.09	0.02	0.14	0.66	0.63	0.27	0.17	0.25	0.38	0.56	0.31	0.51	0.32	0.18	0.57	1.00																		
B20	0.40	0.25	0.65	0.65	0.83	0.81	0.49	0.62	0.00	0.79	0.02	0.07	0.43	0.21	0.39	0.19	0.51	0.32	0.13	1.00																	
B21	0.38	0.18	0.18	0.02	0.36	0.43	0.25	0.23	0.03	0.20	0.14	0.39	0.36	0.03	0.25	0.06	0.56	0.18	0.34	0.37	1.00																
B22	0.27	0.13	0.37	0.27	0.53	0.57	0.40	0.31	0.05	0.38	0.13	0.09	0.02	0.27	0.24	0.10	0.66	0.27	0.02	0.61	0.40	1.00															
B23	0.38	0.29	0.07	0.01	0.08	0.01	0.45	0.31	0.26	0.22	0.61	0.37	0.38	0.07	0.01	0.09	0.28	0.06	0.21	0.21	0.15	0.44	1.00														
B24	0.36	0.53	0.29	0.12	0.22	0.20	0.26	0.48	0.03	0.03	0.08	0.28	0.56	0.34	0.41	0.15	0.64	0.39	0.53	0.20	0.69	0.57	0.13	1.00													
B25	0.43	0.43	0.25	0.01	0.27	0.25	0.29	0.44	0.03	0.16	0.15	0.33	0.56	0.29	0.41	0.18	0.74	0.40	0.57	0.26	0.71	0.57	0.06	0.94	1.00												
B26	0.28	0.61	0.49	0.61	0.14	0.45	0.37	0.39	0.01	0.26	0.70	0.03	0.20	0.01	0.69	0.27	0.16	0.70	0.28	0.35	0.15	0.03	0.45	0.23	0.18	1.00											
B27	0.04	0.16	0.13	0.15	0.30	0.00	0.16	0.06	0.32	0.03	0.51	0.16	0.08	0.24	0.13	0.51	0.13	0.21	0.08	0.10	0.10	0.06	0.16	0.07	0.07	0.41	1.00										
B28	0.39	0.03	0.08	0.26	0.04	0.43	0.44	0.13	0.57	0.45	0.50	0.35	0.07	0.28	0.08	0.57	0.21	0.20	0.03	0.33	0.37	0.36	0.04	0.35	0.42	0.42	0.49	1.00									
B29	0.29	0.01	0.38	0.31	0.25	0.53	0.84	0.59	0.46	0.46	0.04	0.47	0.51	0.05	0.50	0.11	0.20	0.56	0.52	0.56	0.11	0.58	0.46	0.11	0.04	0.38	0.21	0.57	1.00								
B30	0.40	0.52	0.34	0.40	0.37	0.31	0.42	0.11	0.61	0.02	0.52	0.55	0.31	0.05	0.21	0.05	0.05	0.09	0.30	0.14	0.23	0.09	0.71	0.05	0.09	0.46	0.02	0.09	0.40	1.00							
B31	0.47	0.21	0.22	0.46	0.38	0.64	0.47	0.35	0.35	0.67	0.34	0.07	0.19	0.06	0.28	0.17	0.44	0.34	0.18	0.69	0.57	0.50	0.03	0.33	0.41	0.58	0.32	0.76	0.65	0.08	1.00						
B32	0.40	0.06	0.28	0.51	0.60	0.61	0.07	0.07	0.06	0.55	0.31	0.21	0.12	0.12	0.07	0.15	0.67	0.01	0.31	0.69	0.62	0.63	0.06	0.62	0.74	0.22	0.07	0.54	0.29	0.32	0.66	1.00					
B33	0.42	0.54	0.83	0.54	0.42	0.21	0.21	0.55	0.53	0.16	0.03	0.08	0.41	0.16	0.63	0.31	0.18	0.44	0.17	0.33	0.44	0.02	0.09	0.53	0.48	0.27	0.29	0.45	0.06	0.39	0.22	0.06	1.00				
B34	0.09	0.71	0.41	0.50	0.20	0.29	0.15	0.44	0.01	0.43	0.38	0.01	0.39	0.35	0.39	0.04	0.20	0.32	0.21	0.32	0.02	0.25	0.50	0.47	0.32	0.62	0.12	0.10	0.04	0.55	0.33	0.16	0.41	1.00			
B35	0.43	0.31	0.41	0.02	0.01	0.23	0.09	0.32	0.36	0.24	0.29	0.07	0.36	0.17	0.29	0.32	0.50	0.22	0.29	0.18	0.74	0.34	0.15	0.74	0.75	0.15	0.32	0.60	0.25	0.00	0.65	0.51	0.66	0.10	1.00		
B36	0.36	0.21	0.32	0.48	0.63	0.78	0.20	0.28	0.03	0.57	0.23	0.12	0.09	0.30	0.26	0.02	0.56	0.27	0.08	0.73	0.58	0.50	0.12	0.34	0.44	0.43	0.08	0.45	0.40	0.38	0.73	0.70	0.02	0.36	0.49	1.00	
B37	0.15	0.00	0.59	0.41	0.71	0.69	0.33	0.40	0.19	0.47	0.05	0.08	0.10	0.17	0.33	0.15	0.59	0.27	0.08	0.77	0.41	0.76	0.16	0.41	0.46	0.25	0.09	0.27	0.47	0.18	0.47	0.66	0.29	0.05	0.21	0.60	1.00

contact via phone calls followed by email communication outlining the research details and the questionnaire. Respondents were asked to evaluate each barrier and driver on a five-point Likert scale, ranging from 'unimportant' to 'extremely important.' The ratings were assigned values from 1 to 5 (1 = 'unimportant'; 5 = 'extremely important'). Considering the extensive experience of the respondents, their views hold significant weight. The collected data was also validated through telephone conversations. Besides, to

Table 8
Analysis of barriers by stakeholders and category. Values higher than 0.900 are marked.

Categories		Barriers	Overall Average	Govt. *	Manufacturer & Supplier*	Transportation Provider*	Users*	Researchers & Academic*	NGOs*
Technical	B1	Lack of biofuel refuel station/ EV charging station	0.933	0.900	0.944	0.965	0.915	0.913	0.960
	B2	Lack of technical experts	0.799	0.773	0.961	0.806	0.767	0.806	0.680
	B3	Un-availability of proven technology	0.673	0.680	0.936	0.476	0.811	0.656	0.480
	B4	Poor quality services	0.741	0.740	0.885	0.576	0.837	0.838	0.540
	B5	Planning and installation issues	0.715	0.573	0.622	0.865	0.659	0.731	0.840
Economic	B6	Uncertain return on investment	0.698	0.673	0.614	0.776	0.652	0.731	0.740
	B7	Lack of financing opportunities	0.606	0.960	0.408	0.665	0.452	0.513	0.640
	B8	Uncertainties of receiving financial support	0.641	0.840	0.389	0.776	0.537	0.563	0.740
	B9	High initial investment	0.706	0.893	0.728	0.665	0.707	0.600	0.640
	B10	Uncertain development and operational costs	0.673	0.680	0.589	0.776	0.630	0.581	0.780
	B11	Lack of investment incentives	0.760	0.727	0.769	0.776	0.726	0.781	0.780
	B12	High cost for end users	0.575	0.767	0.561	0.576	0.544	0.419	0.580
	B13	Hidden cost	0.471	0.653	0.353	0.576	0.438	0.363	0.440
Social	B14	Perceived negative impacts	0.360	0.280	0.339	0.353	0.426	0.444	0.320
	B15	Lack of sufficient knowledge	0.726	0.567	0.914	0.688	0.811	0.656	0.720
	B16	Lack of awareness about the policies, technology and its benefits	0.860	0.740	0.819	0.865	0.863	0.950	0.920
	B17	Political unwillingness	0.832	0.700	0.808	0.888	0.744	0.931	0.920
	B18	Resistance to change	0.578	0.380	0.736	0.576	0.648	0.488	0.640
	B19	Socio-economic differences between major cities and regional areas	0.506	0.653	0.389	0.376	0.467	0.513	0.640
Policy	B20	Unclear and complex legislative issues	0.742	0.687	0.600	0.929	0.644	0.713	0.880
	B21	Lack of financial policy	0.715	0.613	0.731	0.753	0.715	0.800	0.680
	B22	Insufficient attention from government	0.908	0.900	0.836	1.000	0.770	0.981	0.960
	B23	Bureaucratic complexity	0.765	0.847	0.750	0.824	0.637	0.731	0.800
	B24	Lack of concrete transportation policy	0.930	0.813	0.991	0.976	0.852	0.995	0.940
	B25	Lack of decarbonization strategy/policy	0.931	0.747	0.989	1.000	0.848	0.997	0.994
Market	B26	Immature automobile market	0.837	0.733	0.958	0.847	0.826	0.819	0.840
	B27	Unsettled fuel market	0.837	0.727	0.839	0.924	0.844	0.850	0.840
	B28	Low demand from customer	0.605	0.720	0.575	0.612	0.570	0.550	0.600
	B29	Lack of participation in global carbon market	0.703	0.880	0.600	0.729	0.574	0.713	0.720
	B30	Lack of private support	0.697	0.847	0.736	0.665	0.641	0.656	0.640
	B31	Lack of user experience	0.690	0.733	0.597	0.729	0.648	0.713	0.720
	B32	Competition with fossil fuels	0.666	0.533	0.600	0.812	0.578	0.675	0.800
Organization & competency	B33	Lack of services	0.739	0.800	0.897	0.576	0.774	0.769	0.620
	B34	Poor research & development	0.842	0.860	0.969	0.812	0.752	0.856	0.800
	B35	No unique platform for stakeholders	0.759	0.733	0.808	0.729	0.744	0.819	0.720
	B36	Lack of decarbonization activities experience	0.673	0.613	0.603	0.753	0.641	0.750	0.680
	B37	Lack of co-ordination in decarbonization projects	0.767	0.693	0.619	0.953	0.600	0.819	0.920

*Number of responses: (Govt. = 10; Manufacturer = 36; Transport provider = 17; Users = 27; Research & academia = 16; NGOs = 5).

ensure transparency and accountability, records were kept throughout the data collection process, and all participants were fully informed about the study's purpose.

A total of 111 responses were obtained out of 145, yielding a strong response rate of 76.5 %. Several factors contributed to this high response rate. Notably, the study was actively supported by key personnel within the Bangladesh Road Transportation Authority (BRTA), the main regulatory body in the transportation sector. Their direct involvement played a critical role, as their authoritative position encouraged other organizations—particularly manufacturers and transportation service providers—to participate. In addition to this institutional backing, the research team went beyond standard communication methods such as emails and phone calls. They proactively engaged with other scholars and stakeholders in the transportation sector, fostering meaningful dialogue that enriched the study. The team also leveraged their alumni networks from various universities to broaden the scope of participation. To ensure transparency and accountability, records were kept throughout the data collection process, and all participants were fully informed about the study's purpose.

Nevertheless, the total sample size of 111 respondents, distributed as government (10), manufacturers (36), transport providers (17), users (27), research and academia (16), and NGOs (5), reflects a practical and contextually relevant distribution of engagement levels in the transportation sector. It should be acknowledged that while the research did not utilize a perfectly balanced sample size, such small differences in sample composition do not appear to have a statistically significant impact on the quantitative outcomes (Auspurg et al., 2020; Tipton et al., 2014). However, to address potential biases arising from stakeholder disparities and to ensure the robustness of the findings, the results are presented using multiple approaches, including overall statistical means and stakeholder-specific analyses, to account for variations in stakeholder group sizes (Everitt et al., 2011; Tipton, 2013).

3.4. Data analysis

The subsequent phase of the research focused on analyzing data to rank the identified drivers and barriers in transportation decarbonization based on participant responses. To ensure the reliability and internal consistency of the survey data, Cronbach's alpha test was applied. This test helped confirm that the responses were consistent across the samples, enhancing the credibility of the findings (Christmann & Van Aelst, 2006). The result of the Cronbach's alpha test regarding data reliability was 0.71, thus considered acceptable (Cortina, 1993).

Only responses provided on the numbered Likert scale were considered when calculating the arithmetic means. These mean values were then used to rank the drivers and barriers, with higher scores indicating stronger agreement with a factor being either a driver or a barrier. Notably, this study did not account for discrepancies in perceptions among different participant groups, meaning the analysis treated all responses equally without differentiating between subgroup variations (More & Wolkersdorfer, 2024). After calculating the means, the results were normalized on a scale of 0 to 1 to facilitate comparison and interpretation. This normalization process allowed for a clearer distinction between the importance of each driver or barrier, ensuring all factors were represented on a common scale. Additionally, statistical methods such as correlation analysis and multivariate analysis were employed to gain a deeper understanding of the relationships between various drivers and barriers. Correlation analysis helped identify the strength between different factors, while multivariate analysis provided insights into how multiple variables interacted and influenced each other, offering a more

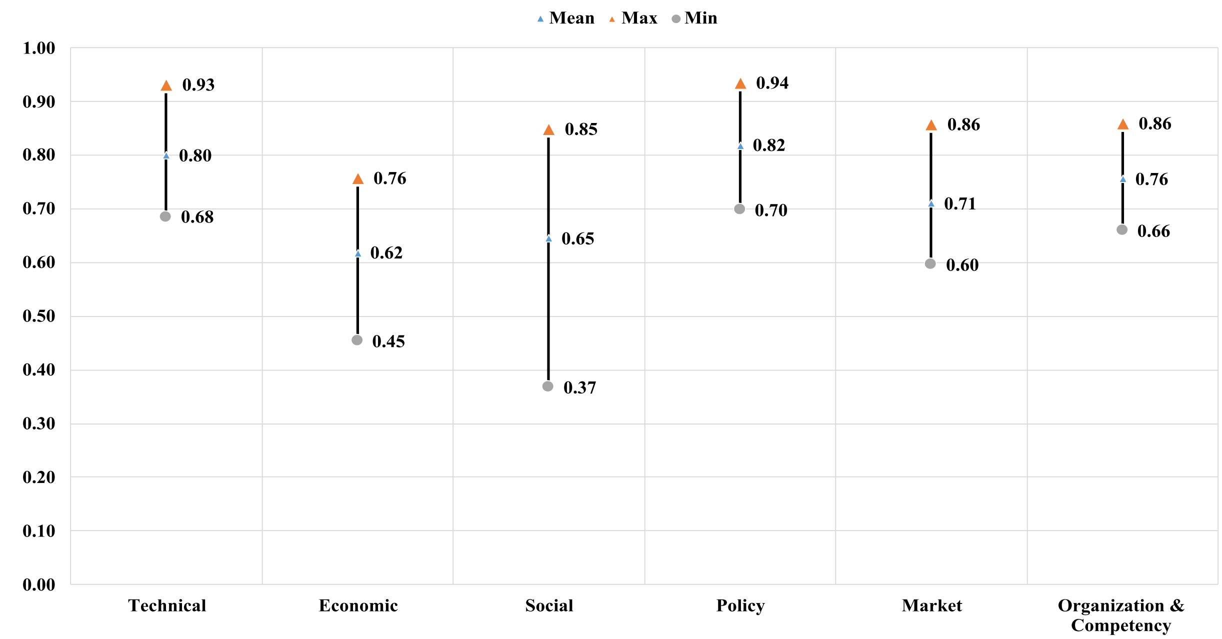

Fig. 3. Multivariable analysis of barriers based on the different categories.

comprehensive understanding of the key elements impacting transportation decarbonization (Hu et al., 2019).

4. Barriers to decarbonization

This section provides a comprehensive analysis of the barriers from multiple perspectives. Section 4.1 examines the overall results, highlighting key barriers across the entire sample and exploring significant statistical correlations. Section 4.2 delves into stakeholder-specific insights, emphasizing which barriers are prioritized by different groups and uncovering distinct patterns of concern. Finally, Section 4.3 categorizes the barriers into broader themes, identifying the critical categories.

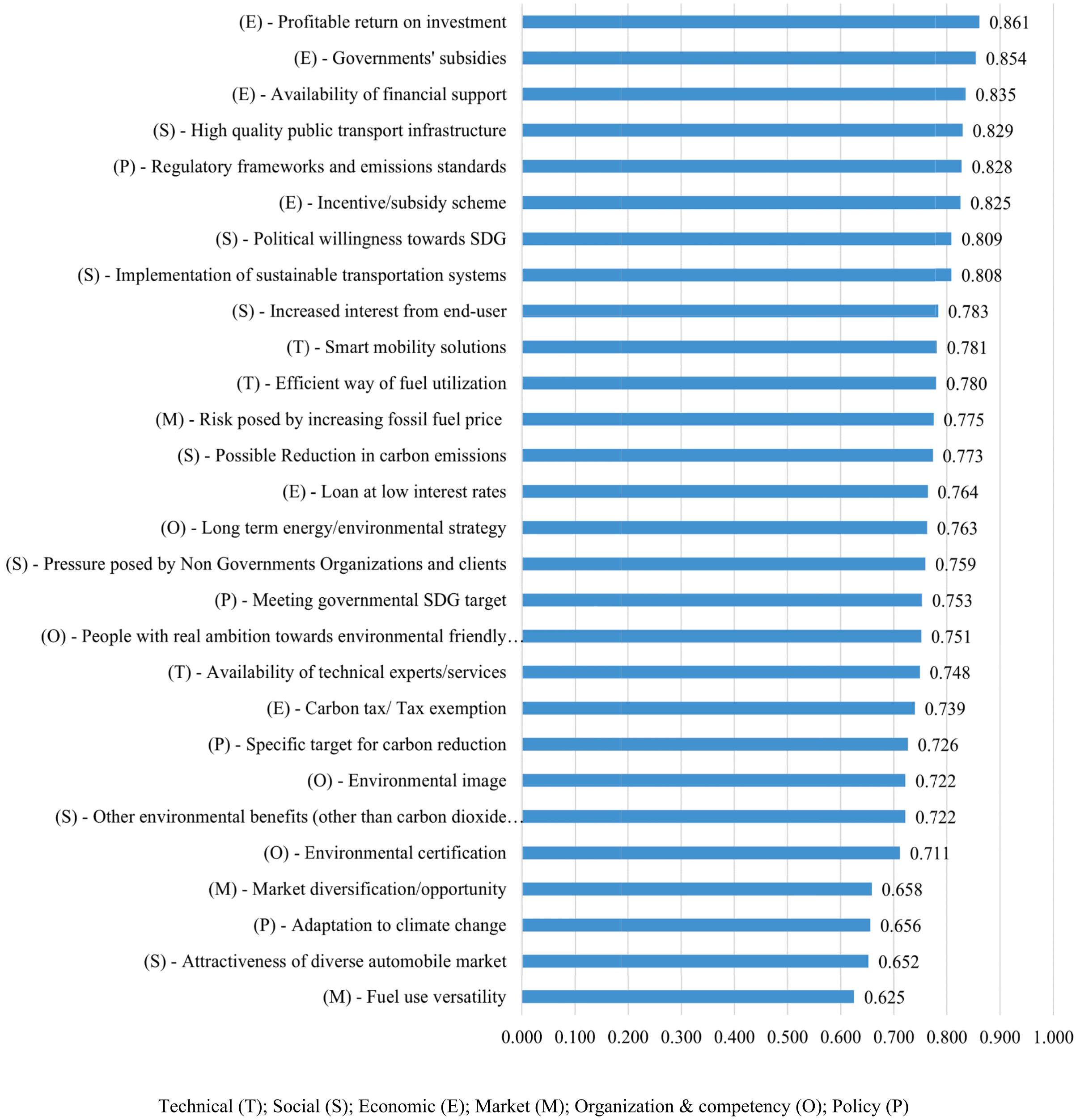

Fig. 4. Analysis of driver by average for whole sample. Technical (T); Social (S); Economic (E); Market (M); Organization & competency (O); Policy (P).

4.1. Analysis of barriers by average for the whole sample

The study undertakes a thorough examination of the barriers (see Fig. 2) impeding decarbonization endeavors within the transportation domain, elucidating a spectrum of concerns alongside their statistical significance. Predominating among these concerns is the conspicuous absence of well-defined transportation policies, closely followed by the inadequacy of biofuel refueling stations and EV charging infrastructure, in addition to the deficiency in comprehensive decarbonization strategies. Furthermore, a noteworthy issue arises from the insufficient attention by governmental entities. On the other hand, the least highlighted barriers appear to be the "Hidden cost" and "Perceived negative impacts".

Barriers to transportation decarbonization vary across studies; however, most research adopts a narrow focus on individual technologies, overlooking broader, interconnected decarbonization strategies. For instance, research in the Philippines on EVs highlights the high cost of EVs as the primary barrier, followed by limited charging infrastructure and insufficient consumer awareness of EV technology (Guno et al., 2021). In India, infrastructure issues were identified as a key barrier, particularly the lack of EV charging stations (R et al., 2024). Similarly, in Thailand, economic factors, including the high cost of EVs, remain the dominant obstacle (Preedakorn et al., 2023). When it comes to biofuels, another means of transport decarbonization, several issues are identified as barriers, including the lack of government support, unclear commercial environmental benefits, and insufficient competitive pressure (Hasan et al., 2022; Zailani et al., 2019). Furthermore, policy mechanisms have been identified as substantial barriers to alternative fuels adoption in Europe, aligning with the findings of this study (Steenberghen & López, 2008). In the context of energy efficiency in transportation, governance issues and inadequate infrastructure are reported as top barriers across European countries such as Bulgaria, Germany, Greece, and Estonia (Bagaini et al., 2020).

Statistical correlation among the individual barrier

An interesting finding from the correlation data presented in Table 7 is the overall lack of correlation among most barriers. This suggests that many of these barriers operate independently and may require distinct strategies to address them effectively. However, two particularly strong correlations stand out.

Firstly, B18 (resistance to change) is strongly correlated with B15 (lack of sufficient knowledge). This strong correlation highlights a critical feedback loop between organizational inertia and knowledge deficits. Interestingly, this is consistent with findings by Kamali Saraji & Streimikiene (2023), who emphasize that resistance to adopting low-carbon solutions often stems from a lack of sufficient knowledge about the operational and economic benefits. Similarly, Rogge and Reichardt (2016) identify inadequate knowledge dissemination as a major barrier to the effective implementation of sustainability policies across industries, including transportation. In this context, scholars have argued that targeted capacity-building initiatives significantly reduced stakeholder pushback and accelerated the adoption of green mobility solutions (Danielis et al., 2022; Haasz et al., 2018). In contrast, regions with weak knowledge transfer mechanisms often face persistent resistance to adopting new policies and technologies (Kaiser & Barstow, 2022).

Moreover, B24 (lack of concrete transportation policy) exhibits a strong correlation with B25 (lack of decarbonization policy), which points to a critical structural barrier. This finding aligns with Lah (2017), who argues that fragmented policies create systemic inefficiencies, leading to missed opportunities for emissions reduction. Similarly, regions such as Sub-Saharan Africa, where fragmented and siloed policy approaches dominate, struggle to address systemic challenges effectively(Akomolafe et al., 2024). Further compounding the issue, Creutzig et al. (2015) claimed that the lack of policy integration undermines potential synergies across sectors, resulting in resource inefficiencies and reinforcing the status quo. In such scenarios, policy silos serve as a major barrier, limiting the capacity for cross-sectoral collaboration and innovation.

4.2. Analysis of barriers by stakeholders

Table 8 highlights key barriers to decarbonization identified by stakeholders. The 'Lack of biofuel refueling/ EV charging stations' emerges as the most significant challenge across all groups. This finding resonates with the argument presented by Creutzig et al. (2015), who contend that inadequate infrastructure is not merely a logistical issue but a structural failure that stifles innovation and deters widespread adoption of sustainable technologies.

On the other hand, government stakeholders recognize limited financing opportunities and insufficient governmental focus as top barriers. In fact, scholars have argued that inadequate funding mechanisms undermine the development and deployment of decarbonized technologies, leaving projects perpetually stalled (Hasan et al., 2022; Tuydes-Yaman et al., 2024). Similarly, insufficient governmental focus weakens the momentum needed for transformative change. In fact, scholars have emphasized that without a unified policy, decarbonization efforts become disjointed, leading to inefficiencies and a failure to address the broader structural issues. A striking example is the inconsistent policy frameworks in some developing regions, where competing priorities weaken efforts to prioritize transportation decarbonization (Li et al., 2024).

For manufacturers and suppliers, major barriers include the absence of clear transportation policies, a lack of comprehensive decarbonization strategies, insufficient R&D, technical expertise gaps, and the immaturity of the automobile market. On the other hand, several barriers are identified by the transportation providers. For instance, alongside the deficiency of biofuel re-fueling stations and EV charging infrastructure, there exists a significant degree of uncertainty regarding complex legislative matters. Moreover, transportation providers emphasize the indispensable role of robust transportation policies, highlighting the importance of steering the sector towards decarbonization. Furthermore, the unsettled nature of the fuel market exacerbates challenges within the transportation sector.

When looking at user perspectives, their focal point centers on the absence of biofuel refueling stations, a barrier consistently

Table 9
Statical correlation analysis among the drivers. Values more than 0.850 are marked.

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28
D1	1.00																											
D2	0.46	1.00																										
D3	0.66	0.14	1.00																									
D4	0.46	0.33	0.46	1.00																								
D5	0.38	0.42	0.26	0.12	1.00																							
D6	0.20	0.15	0.55	0.25	0.46	1.00																						
D7	0.05	0.03	0.08	0.16	0.47	0.42	1.00																					
D8	0.08	0.28	0.07	0.17	0.12	0.17	0.24	1.00																				
D9	0.03	0.20	0.40	0.31	0.18	0.17	0.53	0.17	1.00																			
D10	0.03	0.32	0.19	0.33	0.60	0.70	0.71	0.15	0.32	1.00																		
D11	0.08	0.39	0.26	0.06	0.02	0.14	0.42	0.52	0.32	0.31	1.00																	
D12	0.33	0.18	0.60	0.25	0.06	0.36	0.35	0.48	0.43	0.05	0.79	1.00																
D13	0.25	0.57	0.31	0.29	0.23	0.03	0.43	0.51	0.24	0.40	0.88	0.79	1.00															
D14	0.11	0.78	0.11	0.09	0.08	0.08	0.26	0.16	0.28	0.11	0.37	0.88	0.40	1.00														
D15	0.00	0.41	0.21	0.02	0.05	0.22	0.24	0.30	0.31	0.30	0.89	0.37	0.82	0.50	1.00													
D16	0.55	0.51	0.49	0.66	0.23	0.12	0.16	0.44	0.08	0.02	0.56	0.89	0.68	0.28	0.39	1.00												
D17	0.10	0.28	0.34	0.13	0.02	0.10	0.52	0.59	0.36	0.27	0.94	0.56	0.83	0.14	0.77	0.58	1.00											
D18	0.23	0.36	0.42	0.32	0.38	0.00	0.06	0.42	0.08	0.21	0.52	0.94	0.36	0.56	0.56	0.03	0.38	1.00										
D19	0.54	0.27	0.52	0.14	0.37	0.05	0.52	0.35	0.33	0.47	0.61	0.52	0.59	0.02	0.49	0.54	0.67	0.10	1.00									
D20	0.07	0.55	0.37	0.08	0.27	0.56	0.14	0.37	0.33	0.58	0.34	0.61	0.37	0.43	0.38	0.20	0.27	0.53	0.42	1.00								
D21	0.21	0.43	0.25	0.05	0.05	0.51	0.32	0.15	0.18	0.09	0.26	0.34	0.18	0.64	0.48	0.00	0.12	0.41	0.08	0.08	1.00							
D22	0.34	0.78	0.16	0.22	0.23	0.33	0.05	0.34	0.36	0.24	0.13	0.26	0.27	0.66	0.01	0.43	0.05	0.30	0.04	0.42	0.16	1.00						
D23	0.32	0.64	0.25	0.11	0.30	0.59	0.19	0.49	0.37	0.46	0.13	0.13	0.25	0.39	0.07	0.34	0.13	0.29	0.26	0.63	0.13	0.79	1.00					
D24	0.20	0.38	0.28	0.13	0.31	0.58	0.00	0.18	0.40	0.29	0.22	0.13	0.04	0.13	0.30	0.11	0.19	0.05	0.03	0.47	0.21	0.56	0.67	1.00				
D25	0.13	0.02	0.23	0.07	0.45	0.42	0.20	0.52	0.29	0.12	0.79	0.22	0.63	0.15	0.66	0.39	0.80	0.47	0.30	0.10	0.15	0.08	0.13	0.45	1.00			
D26	0.28	0.33	0.55	0.17	0.04	0.51	0.12	0.18	0.40	0.08	0.79	0.79	0.74	0.37	0.88	0.46	0.71	0.32	0.57	0.12	0.58	0.12	0.25	0.40	0.63	1.00		
D27	0.03	0.12	0.34	0.01	0.41	0.63	0.04	0.33	0.40	0.19	0.71	0.79	0.52	0.30	0.69	0.22	0.67	0.52	0.22	0.18	0.54	0.10	0.27	0.54	0.88	0.74	1.00	
D28	0.60	0.84	0.21	0.30	0.60	0.22	0.03	0.09	0.21	0.33	0.16	0.71	0.29	0.59	0.18	0.47	0.08	0.07	0.36	0.56	0.39	0.70	0.62	0.47	0.31	0.16	0.18	1.00

acknowledged by all other stakeholder groups. Intriguingly, research institutions and academic bodies, alongside NGOs, align in identifying predominantly policy-related impediments. Furthermore, both stakeholder cohorts emphasize a notable deficiency in awareness regarding policies, technologies, and their attendant benefits. Scholars have supported this perspective. For instance, Tuydes-Yaman et al. (2024) argue about the infrastructure limitations, such as insufficient refueling and recharging stations, are a significant impediment to the widespread adoption of alternative transportation technologies. Additionally, scholars also argue that policy frameworks and a lack of coordination often hinder technological advancements and industry-wide implementation (Jacquemin et al., 2025). Moreover, the lack of public and industry awareness about the policies and technologies is frequently cited as a key barrier to adoption of decarbonized road transportation system (Virmani et al., 2023; R. Zhang et al., 2025).

4.3. Analysis of barriers by category

In this research, a total of 37 potential barriers were identified in six different categories, i.e., technical, economic, social, policy, market and organization & competency. The responses arranged category-wise were put through a multivariable analysis based on three variables – mean, maximum (max) and minimum (min) for each category.

The findings (see Fig. 3) underscores that policy barriers, as a whole, often dominate and significantly hinder the decarbonization of the transport sector. Despite varying perspectives among stakeholders, the maximum value of 1 and the minimum value of 0.4 in the policy category reveal a clear consensus: policy-related challenges are seen as the most prominent obstacles. In this context, Creutzig et al. (2012) argue that without comprehensive and well-structured policies—such as carbon pricing, regulatory standards, and investment in green infrastructure—technological advancements and market solutions alone are insufficient to drive significant change in the transport sector. Similarly, Wang et al. (2018), argue that policy uncertainty can slow down the deployment of green technologies, even when these technologies are available. The importance of a well-designed policy environment is further reinforced by the work of Lah (2017), who argues that policies that integrate environmental, social, and economic goals are necessary to ensure the widespread adoption of clean technologies and address systemic barriers in sectors like transport.

The technical category exhibits analogous prominence likewise to the policy domain, as evidenced by comparable patterns in the obtained results. Technical challenges—such as lack of technical expertise, poor-quality services, or planning and installation issues—are fundamental in hindering the decarbonization of the transport sector. For instance, without sufficient technical expertise in areas such as EV maintenance and infrastructure development, the rapid scaling of EVs becomes virtually challenging (Sandaka & Kumar, 2023; Singh et al., 2024). Besides, the lack of EV charging stations and biofuel refueling stations further exacerbates this issue, as inadequate infrastructure limits consumer adoption of clean technologies. Moreover, poor planning and installation practices lead to inefficient systems and operational delays, which hinder and slow down the transition to a low-carbon transport system (Sarda et al., 2024).

5. Drivers to decarbonization

This section offers a detailed analysis of the drivers from various perspectives. Section 5.1 focuses on the overall results, identifying key drivers across the entire sample and examining significant statistical correlations. Section 5.2 explores stakeholder-specific insights, highlighting the drivers prioritized by different groups and uncovering unique patterns of emphasis. Finally, Section 5.3 categorizes the drivers into broader themes, identifying the critical categories that demand attention for effective decarbonization strategies.

5.1. Analysis of driver by average for whole sample

In this section, a concise presentation of the drivers of decarbonization in the transportation sector is provided. A total of 28 drivers were assessed, with 'profitable return on investment', 'government subsidies', and 'availability of financial support' emerging as the high-ranked drivers. Following closely was 'high-quality public transport infrastructure' and 'political willingness towards SDGs.' In contrast, the least significant drivers encompass adaptation to market diversification, adaptation to climate change, attractiveness to diverse automobile markets, and fuel use versatility. Detailed values for each driver are presented in Fig. 4.

Contrasting our findings with other relevant studies highlights both alignment and divergence in the identified drivers. While this study emphasizes financial drivers as the top three motivators, studies from the Philippines prioritize infrastructure-related factors, such as the establishment of necessary charging infrastructure (Guno et al., 2021). Similarly, in India, public awareness emerges as the most critical driver, a finding echoed in other studies that also highlight 'increased awareness among people' as essential for driving adoption (R et al., 2024; Shah et al., 2021). In contrast, our findings align more closely with studies from Singapore, China, the USA, Malaysia, and South Korea, where financial drivers—particularly 'government subsidies' and 'tax rebates'—dominate as the primary enablers (Jenn et al., 2018; Lee et al., 2022; Muzir et al., 2022; Shah et al., 2021). In Europe, the narrative is more diverse, with drivers including 'market incentive (Khurshid, Khan, Saleem, et al., 2023; Steenberghen & López, 2008). Despite these regional differences, financial incentives, robust infrastructure, and effective policy frameworks consistently emerge as essential across contexts.

Statistical correlation among the individual driver

Whilst analyzing Table 9, several noteworthy statistical correlations are observed. Specifically, the correlation between D11 (other environmental benefits) and D17 (implementation of sustainable transportation systems) suggests that the implementation of sustainable transportation systems is closely linked with other environmental benefits. This linear relation of D11 and D17 are also

Table 10
Analysis of drivers by stakeholders and category. Values higher than 0.90 are marked.

Categories		Drivers	Govt.	Manufacturer & Supplier	Transportation Provider	Users	Researchers & Academic	NGOs	Overall Average
Technical	D1	Efficient way of fuel utilization	0.707	0.831	0.806	0.770	0.750	0.700	0.761
	D2	Availability of technical experts/services	0.587	0.719	0.820	0.850	0.731	0.720	0.831
	D3	Smart mobility solutions	0.747	0.836	0.844	0.738	0.738	0.660	0.738
Economic	D4	Profitable return on investment	0.847	0.797	0.919	0.945	0.825	0.840	0.760
	D5	Availability of financial support	0.667	0.747	0.950	0.937	0.894	0.860	0.862
	D6	Incentive/subsidy scheme	0.667	0.924	0.844	0.786	0.919	0.880	0.843
	D7	Loan at low interest rates	0.887	0.747	0.800	0.723	0.675	0.660	0.826
	D8	Carbon tax/ Tax exemption	0.733	0.864	0.669	0.611	0.775	0.660	0.762
	D9	Governments' subsidies	0.620	0.904	0.944	0.920	0.838	0.900	0.719
Social	D10	Possible Reduction in carbon emissions	0.993	0.631	0.851	0.786	0.769	0.840	0.848
	D11	Other environmental benefits (other than carbon dioxide reduction)	0.800	0.631	0.850	0.792	0.631	0.640	0.811
	D12	Attractiveness of diverse automobile market	0.953	0.514	0.756	0.607	0.681	0.560	0.724
	D13	Increased interest from end-user	0.820	0.747	0.931	0.614	0.950	0.840	0.679
	D14	Political willingness towards SDG	0.960	0.631	0.853	0.807	0.938	0.980	0.817
	D15	High quality public transport infrastructure	0.893	0.836	0.894	0.800	0.756	0.780	0.868
	D16	Pressure posed by NGOs and clients	0.973	0.636	0.820	0.800	0.688	0.820	0.827
	D17	Implementation of sustainable transportation systems	0.880	0.831	0.885	0.610	0.885	0.840	0.789
Policy	D18	Meeting governmental SDG target	0.907	0.669	0.788	0.707	0.825	0.800	0.783
	D19	Adaptation to climate change	0.733	0.636	0.600	0.700	0.613	0.640	0.654
	D20	Specific target for carbon reduction	0.890	0.753	0.600	0.614	0.775	0.820	0.746
	D21	Regulatory frameworks and emissions standards	0.740	0.753	0.944	0.792	0.981	0.960	0.862
Market	D22	Market diversification/opportunity	0.733	0.753	0.856	0.422	0.619	0.520	0.650
	D23	Fuel use versatility	0.807	0.753	0.669	0.422	0.525	0.440	0.603
	D24	Risk posed by increasing fossil fuel price	0.727	0.667	0.800	0.889	0.825	0.840	0.791
Org. & competency	D25	Environmental certification	0.867	0.553	0.850	0.792	0.656	0.680	0.733
	D26	People with real ambition towards environmentally friendly technologies/services	0.800	0.631	0.800	0.792	0.838	0.820	0.780
	D27	Environmental image	0.773	0.553	0.894	0.785	0.756	0.780	0.757
	D28	Long term energy/environmental strategy	0.747	0.836	0.800	0.607	0.800	0.880	0.778

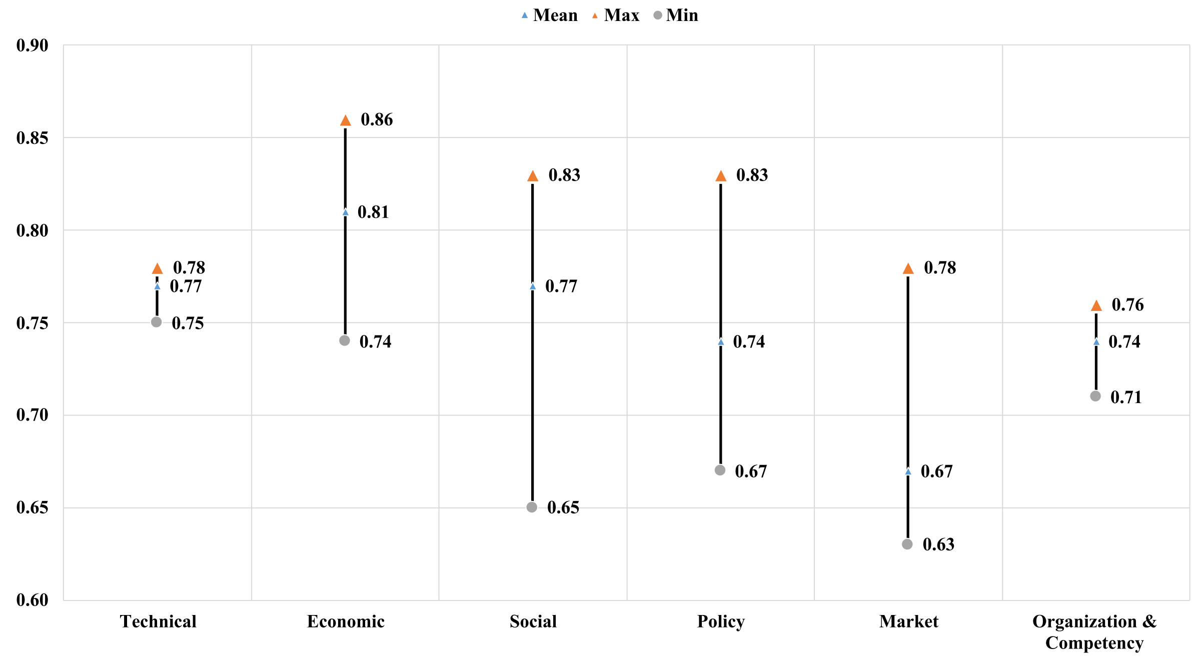

Fig. 5. Multivariable analysis of drivers based on the different categories.

evident by other researchers, for instance, Shah et al. (2021) argued that implementation of sustainable strategies provides environmental benefits in addition to carbon emission. Similarly, Kwilinski et al. (2024) demonstrated that sustainable transportation infrastructure can reduce carbon emissions by encouraging low-carbon mobility, while also contributing to public health improvements and behavioral shifts.

On the other hand, D11, and D15 (High-quality public transport infrastructure) have a strong correlation which suggests a significant interdependence between environmental outcomes and the quality of public transportation systems. High-quality public transport infrastructure can lead to reduced reliance on private vehicles, thereby decreasing greenhouse gas emissions and improving air quality. This, in turn, enhances other environmental benefits such as reduced urban sprawl, lower noise pollution, and better public health outcomes. In this regard, scholars also highlighted that well-designed and planned public transport infrastructure, apart from the obvious effect of decreased number of private vehicles and decreased congestion, can contribute to reduced air pollutant emissions and become a significant driver for the implementation of electromobility in cities (Pietrzak & Pietrzak, 2020).

Furthermore, D11 (other environmental benefits) demonstrates significant correlations with D13 (increased interest from end users). This relationship indicates that as environmental benefits become more apparent, end users are more likely to engage with and support sustainable initiatives. In fact, studies have highlighted that more interest from end-user in transportation decarbonization, specifically in active transportation, would enhance others environmental benefit (Jelti et al., 2023; Kłos & Sierpiński, 2021).

Simultaneously, D15 (High-quality public transport infrastructure) demonstrates a significant correlation with D26 (People with real ambition). This correlation highlights the potential influence of an ambitious population on the development and maintenance of high-quality public transport systems. In fact, the presence of ambitious people can drive innovation and improvement in public transport infrastructure through various channels. They may push for policy changes, secure funding for infrastructure projects, and engage in urban planning efforts that prioritize public transport. Their ambition can also lead to the adoption of new technologies and best practices, ensuring that the public transport system is not only high-quality but also forward-looking and adaptable to future needs. Additionally, D25 (Environmental certification) shows a strong correlation with D27 (Environmental image). Here, this relationship emphasizes the importance of formal recognition and certification in shaping public perceptions and enhancing an entity's environmental image. To illustrate this relation further, Gouda & Masoumi (2017) described the relevancy of urban sustainable certification with different local conditions in developing countries. However, the thematic idea of sustainable transportation should be tailored to the local conditions rather than being adopted only from perspective.

5.2. Analysis of drivers by stakeholders

Table 10 outlines stakeholders' perspectives on drivers for decarbonization. When examining the drivers as perceived by stakeholders, government stakeholders prioritize aimed at reducing carbon emissions, enhancing attractiveness to diverse automobile markets, demonstrating political commitment towards SDGs, responding to pressure from NGOs and clients, and meeting governmental SDG targets as high-priority initiatives. Interestingly, government priorities diverge significantly from those of other stakeholders in their selected drivers. Conversely, manufacturers and suppliers prioritize incentive/subsidy schemes, along with government subsidies, as prominent drivers. Similarly, transportation providers prioritize economic drivers, particularly focusing on profitable return on investment, availability of financial support, government subsidies, increased interest from end users, and regulatory frameworks and emission standards as highly identified drivers.

While looking at the users' perspective, certain priorities in drivers become evident. Notably, users prioritize factors such as profitable returns on investment, availability of financial support, and government subsidies. Conversely, research and academia place emphasis on incentives/subsidy schemes, increased interest from end users, political willingness towards SDG, and regulatory frameworks and emission standards. Interestingly, there is a significant alignment in opinions about drivers among stakeholders in NGOs and academia, indicating a consensus on key drivers for decarbonization.

Upon analyzing the drivers by stakeholders, several critical findings emerge, illuminating key priorities and strategic focal points across stakeholder groups. Firstly, a predominant consensus among stakeholders highlights the pivotal role of incentive/subsidy schemes in incentivizing and accelerating decarbonization efforts within the transport sector. This underscores the fundamental importance of providing economic incentives to stimulate the adoption of sustainable practices and technologies (Paipa-Sanabria, 2022; Tsoi et al., 2021). Furthermore, government subsidies emerge as another significant driver identified by many stakeholders. This recognition underscores the crucial role of governmental support and financial incentives in facilitating the transition towards low-carbon transportation systems. Additionally, the regulatory framework emerges as a prominent driver identified by multiple stakeholder groups, highlighting the indispensable role of robust regulatory frameworks and emission standards in shaping industry practices, driving innovation, and ensuring compliance with environmental targets (Axsen et al., 2020; Thalmann & Vielle, 2019; Tsoi et al., 2021).

5.3. Analysis of driver by category

In the evaluation of each driver across all categorical domains, a prevailing trend emerges wherein the foremost drivers for expediting decarbonization predominantly pertain to economic drivers (see Fig. 5). These encompass factors including financial viability, cost-effectiveness, and investment returns, indicative of the overarching significance accorded to economic imperatives in steering decarbonization initiatives within the transport sector. In this regard, Beccarello and Di Foggia (2023) argued about the economic and technical drivers as major mechanism towards decarbonization in Italy, within the framework of recent European Union climate policies. Apart from technical drivers, capital investment in this area identified as main in decarbonization drivers. Similarly, Emodi et al. (2022) and Hardman et al. (2017) highlighted that governments can introduce special economic mechanisms, such as tax reductions, subsidies, and incentives, to support decarbonization.

Furthermore, the social and policy category emerges as another dominant driver, reflecting the intrinsic role of societal values, consumer preferences, and stakeholder engagement in shaping the trajectory of sustainable transportation transitions. The policy categories exhibit notable prominence, underscoring the criticality of regulatory frameworks, legislative mandates, and governmental interventions in driving systemic change towards decarbonization goals. In many cases, policy and social drivers are interconnected with each-other, for example, Langbroek et al. (2016) highlighted the effect of policy incentives on EV-adoption as well as the influence of socio-psychological determinants.

On the contrary, technical, market, and organization & competency-related drivers do not ascend to the forefront as predominant catalysts for change. Amidst this context, an intriguing observation emerges that technical drivers exhibit the least disparity between the maximum and minimum values. Although, scholars argue that technical innovation could be enabler in the reduction of carbon footprints in the transportation sector (Khurshid, Khan, Chen, et al., 2023). Similarly, studies also examined the EV charging market and highlight that clear roles for public and public actors, along with strategic policies, are key to expanding the necessary infrastructure for large scale EV adoption (LaMonaca & Ryan, 2022).

6. Discussion

The academic significance of this study is imperative, primarily attributed to its comprehensive exploration of barriers and drivers pertinent to the decarbonization of the road transportation sector. In fact, this study holds notable importance for adopting a multifaceted approach by examining barriers and drivers from three distinct perspectives consisting individual analysis, categorical analysis, and stakeholder focused analysis, thereby facilitating a detailed understanding of the complexities inherent in the decarbonization process. Such contexts present unique challenges and opportunities, making this study essential for strategic planning, and decision-making processes tailored to address the specific needs and dynamics of such settings. Consequently, this study is imperative in shaping policy discourse and fostering sustainable development trajectories within other densely populated, emerging economies.

This research investigates 37 barriers and 28 drivers within six distinct categories to discern the predominant factors influencing decarbonization in Bangladesh. It is evident from the result that "*lack of a concrete transportation policy*," "*lack of biofuel refueling stations/EV charging stations*," "*lack of a decarbonization strategy/policy*" constitute the most noteworthy barriers of the entire sample. Similarly, "*profitable return on investment*", "*government subsidies*", and "*availability of financial support*" are identified as the top drivers for decarbonization in road transportation. Furthermore, the detailed analysis of barriers and drivers by category also offers valuable insights. One notable finding is that the category identified as "policy barriers" are identified as the most critical barriers indicating that policy-related issues are particularly significant for diffusion of decarbonization actions. Conversely, when it comes to drivers, "economic drivers" stand out as high, suggesting that economic factors are prominent in facilitating decarbonization progress.

Interestingly, the fact that economic factors are not the top barriers, yet they are leading drivers, reveals an important insight within the discourse of transportation decarbonization. This observation prompts a deeper examination of the nexus between economic dynamics and the impediments to decarbonization transition. Scholars have argued the importance of economic actions in overcoming fundamental barriers to decarbonization (Zhang et al., 2022). Likewise, scholars also have deduced that economic drivers play a pivotal role in decarbonization and can help policymakers in formulating policies that harmonize with those of supranational entities (Beccarello & Di Foggia, 2023).

Furthermore, researchers highlighted that economic drivers wield a multifaceted influence that extends beyond mere financial considerations, and they possess the capacity to transcend traditional boundaries and address not only economic barriers but also non-economic barriers impeding decarbonization efforts (Meckling et al., 2017; Peñasco & Anadón, 2021). This assertion finds resonance in empirical evidence suggesting that economic incentives can serve as potent catalysts for raising awareness among end-users, catalyzing behavioral shifts, and fostering a culture of sustainability, irrespective of prevailing financial constraints hindering the implementation of energy-efficient measures (Trianni et al., 2017). Moreover, economic mechanisms such as subsidies, tax incentives, and investment schemes have demonstrated their efficacy in stimulating innovation, driving technological advancements, and catalyzing market demand for sustainable transportation solutions (Godínez-Zamora et al., 2020; Lah, 2017). Although, this study proposes a parallel pattern of findings, indicating that economic incentives are more prominent in surmounting obstacles to decarbonization efforts. However, there are also necessities of fostering collaboration between the public and private sectors and emphasize the role of long-term planning in different modes of economic and policy coherence (Boudet et al., 2021).

Another crucial perspective of this study is that policy-related barriers are highly ranked by multiple stakeholders. Interestingly, government stakeholders, who are the primary actors in policy formulation, also identified "*Insufficient attention from government*" as the top barrier in the policy category. This highlights the need for more suitable policy and regulatory frameworks for transportation decarbonization. In fact, when examining other examples of decarbonized transportation initiatives, policy issues are critically highlighted. In the context of developing countries, policy barriers become even more significant. For instance, emerging countries like Nepal, Malaysia in Asia, face substantial policy barriers. Guno et al. argue that policy barriers pose significant challenges to decarbonization, particularly in developing countries where implementing appropriate policy measures can be difficult (Asadi et al., 2022; Goel et al., 2021; Guno et al., 2021).

Whilst looking at individual barriers, one top barrier identified is the "*lack of biofuel re-fueling stations/ EV charging stations*". Though this is primarily a techno-infrastructure related issue, it is also intrinsically linked to policy. Establishing charging stations and biofuel stations requires substantial support from policy and government frameworks (Murugan & Marisamynathan, 2022). This underscores the essential role of policy in facilitating the deployment of necessary infrastructure for decarbonization technologies. Additionally, in the context of developing countries, policy barriers have become even more pronounced. Limited administrative capacity, insufficient funding, and political instability can hinder the formulation and execution of effective policies. For example, in countries like Nepal, and Malaysia policy barriers significantly impede the establishment of necessary infrastructure for decarbonization. In fact, without robust policies that address these challenges, the adoption of environmental technologies may remain sluggish.

Addressing the barriers to and supporting decarbonization in the transport sector requires multifaceted approaches that align with broader climate goals and facilitate consistent policy implementation. For instance, countries like Sweden and Norway have implemented carbon pricing, emissions standards, and vehicle taxation, leading to substantial reductions in carbon emissions from transportation. Additionally, public awareness, political willingness, behavioral change, congestion pricing, and educational campaigns in Japan, Denmark, the Netherlands, Germany, and the UK have encouraged the adoption of greener transportation alternatives (Lau, 2022; Nagaj et al., 2024; Perissi & Jones, 2022). Similarly, prioritizing investments in public transit systems, cycling lanes, and EV charging networks has also supported decarbonization in these countries. Besides, there is a growing concern for non-motorized, shared, and collective transport in metropolitan areas and the deployment of electro-mobility as key enablers of decarbonization in the passenger transport sector (Briand et al., 2023).

6.1. Policy implications to decarbonize road transport

While discussing policies and their implications, it is essential to acknowledge that no single solution fits all contexts (Noussan et al., 2020). Policymakers need to craft a strategic mix of approaches, including infrastructure investments, economic incentives, stringent regulations, technological innovation, and transparent public engagement, to align with each country's unique challenges and opportunities (Santos et al., 2010).

A critical policy implication for Bangladesh is the urgent need to support the development of transport infrastructure to overcome the barrier of "*lack of biofuel refueling stations/EV charging stations*". In fact, policies need going beyond general frameworks to focus on designing a comprehensive fuel network and EV charging infrastructure. This includes outlining operational standards, identifying responsible parties for operation, and establishing viable operating models (Hainsch, 2023). Furthermore, policies need to address how the national electricity grid will accommodate the growing demand from EV charging stations without overloading existing infrastructure. This could involve upgrading grid capacity, integrating renewable energy sources, and implementing smart grid technologies to optimize energy distribution (Huo et al., 2024). Given Bangladesh's energy crisis, it is essential that policies ensure that new infrastructure, particularly for EVs and biofuels, does not further strain the energy value chain but instead enhances efficiency and sustainability (Abdullah-Al-Nahid et al., 2023; Hasan et al., 2022).

While financial drivers are the primary factors identified in this study, policies play a crucial role in shaping these financial actions. Therefore, they must be clearly formulated and implemented to ensure individuals are adequately supported in adopting decarbonization-friendly transportation modes. Long-term subsidy strategies and effective public information campaigns to encourage higher vehicle occupancy remain challenging. Nevertheless, when combined with investments in clean technologies, infrastructure and regulation, these actions can serve as powerful levers to drive decarbonization in the transport sector.

From an economic perspective, it is essential for governments to carefully time tax reforms within their decarbonization plans, particularly considering the potential fiscal impacts (Victor-Gallardo et al., 2024). Tax incentives and rebates for individuals adopting EVs and blended biofuels are needed to be considered. A multifaceted approach, combining various tax options, will help to ensure fair cost distribution, moderate tax increases, and ultimately, greater public acceptance (Patil et al., 2024). Policymakers may focus on long-term fiscal stability, cost-effectiveness, equity, and political acceptability (Lah, 2017). While carbon taxes and EV incentives support decarbonization, they risk eroding the tax base over time. Therefore, the government needs to be proactive in adjusting tax policies to maintain fiscal health and ensure the sustainability of decarbonization efforts (Haasz et al., 2018).

Additionally, policies need to prioritize the development of low-emission public transport systems, acknowledging that this requires substantial infrastructure investments and broader policy discussions (Qiu et al., 2020). However, while public transport is crucial, focusing on individual transport options, particularly the electrification of vehicles such as electric motorcycles and three-wheelers (E3Ws), offers a more immediate and feasible pathway to decarbonization. This is especially pertinent in Bangladesh, where motorcycles and E3Ws dominate the transport sector, particularly in rural and suburban areas (Hossain, Hasanuzzaman, & Khan, 2022). These vehicles provide an affordable, scalable solution to reduce emissions and transition towards cleaner energy, making them a critical component of the national decarbonization strategy. Integrating the electrification of these individual transport modes into broader policy frameworks could catalyze significant progress in reducing the carbon footprint of the transportation sector without waiting for large-scale infrastructure changes (Santos, 2017).

7. Conclusion and further research avenues

The main objective of our research work is to explore the barriers and drivers for the decarbonization of the road transportation sector in Bangladesh. This study involves reviewing existing literature, formulation of questionnaires, data collection and analysis, and the interpretation of findings. According to the author's best knowledge, there are limited studies that have highlighted the barriers and drivers to the decarbonization of road transport in an emerging economic context, making the results of this research a pioneering exploration into the decarbonization initiatives.

The key outcomes of the study are summarized below:

- The topmost identified barriers are “lack of concrete transportation policy”, “lack of biofuel refueling station/EV charging station”, and “lack of decarbonization policy”.
- Different stakeholders identify different barriers. However, “lack of biofuel refueling station/EV charging station’ dominates in all the stakeholders. Besides, policy related barriers and technical related barriers are predominantly identified by all stakeholders.
- In the statistical correlation analysis of individual barriers, strong correlations are observed between “resistance to change” and “lack of sufficient knowledge”. Besides, there is a strong correlation between “lack of concrete transportation policy” and “lack of decarbonization policy”.
- “Profitable return on investment”, “government subsidies“, and “availability of financial support” have emerged as the top drivers.
- According to categorical analysis of the drivers, economic drivers are the most prevailing followed by policy drivers and social drivers.
- Strong correlations are observed between several drivers. In particular, “other environmental benefits” correlate with “implementation of sustainable transportation systems”, “increased interest from end users”, and “high-quality public transport infrastructure”. Additionally, “high-quality public transport infrastructure” correlates with “people with real ambition”, and “environmental certification” correlates with “environmental image”.

Despite its novel contribution to the field, this study presents several limitations that warrant careful consideration. Foremost among these is its reliance on a restricted number of responses gathered from six distinct stakeholders. Besides, the study has considered people with knowledge on transport decarbonization excluding the general public's perception of the research topic. While these individuals undoubtedly provide valuable insights, the scope of this participants poll may restrict the generalizability of the findings to a broader population. Furthermore, the uneven distribution of stakeholders across the sample may cause potential bias in representing the results. Therefore, any conclusions drawn from this study should be cautiously interpreted within the context of these limitations, emphasizing the need for future research to expand the participant base and ensure a more balanced representation across stakeholder groups.

Considering the limitations, several compelling opportunities for future research emerge. To begin with, future studies, especially if relying on a much larger dataset of respondents, could employ more sophisticated statistical techniques (i.e. cluster analysis, principal component analysis) to achieve a deeper understanding of the challenges inherent in decarbonization efforts. This approach would enhance the identification of specific barriers and enable the development of targeted strategies to overcome them. Furthermore, it is essential to examine the socio-economic impacts of decarbonization policies across various demographic groups within the country. In this regard, future research could explore the role of a set of other contextual factors such as (e.g. gender, age, level of income) in affecting the barriers and drivers towards decarbonising road transportation in emerging economies that have been preliminarily explored in this study. Finally, future research should focus on the development of a comprehensive supporting mechanism or framework to facilitate decarbonization, considering both the barriers and drivers. This would involve a detailed analysis of the factors that hinder or promote decarbonization efforts, enabling the creation of strategies that can effectively address these elements. It would be particularly interesting to observe how a decarbonizing framework interacts with various socio-economic factors, potentially revealing unique insights into the most effective approaches for different contexts.

CRediT authorship contribution statement

Minhazul Alam: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation. **A K M Rakib:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **A S M Monjurul Hasan:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Md Nazrul Islam Siddique:** Writing – review & editing, Writing – original draft. **Md. Ahsan Kabir:** Writing – review & editing, Writing – original draft. **Andrea Trianni:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We acknowledge all the participants who contributed to this study, and we are grateful to the reviewers for their valuable feedback, which greatly helped improve the quality of this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trd.2025.104723.

Data availability

The data that has been used is confidential.

References

Abdullah-Al-Nahid, S., Jamal, T., Aziz, T., Bhuiyan, A.H., Khan, T.A., 2023. Additive linear modelling and genetic algorithm based electric vehicle outlook and policy formulation for decarbonizing the future transport sector of Bangladesh. *Transp. Policy* 136, 21–46. https://doi.org/10.1016/J.TRANPOL.2023.02.005.

Adamashvili, N., & Thrassou, A. (2024). Towards sustainable decarbonization: Addressing challenges in electric vehicle adoption and infrastructure development. *Energies 2024, 17*(21), 5443. Doi: 10.3390/EN17215443.

Adhikari, M., Ghimire, L. P., Kim, Y., Aryal, P., & Khadka, S. B. (2020). Identification and analysis of barriers against electric vehicle use. *Sustainability 2020, 12*(12), 4850. Doi: 10.3390/SU12124850.

Ahasan, R., Hoda, M.N., Alam, M.S., Nirzhar, Y.R., Kabir, A., 2023. Changing institutional landscape and transportation development in Dhaka, Bangladesh. *Heliyon* 9 (7), e17887. https://doi.org/10.1016/j.heliyon.2023.e17887.

Ahmed, M. R., & Karmaker, A. K. (2019). Challenges for electric vehicle adoption in Bangladesh. *2nd International Conference on Electrical, Computer and Communication Engineering, ECCE 2019*. Doi: 10.1109/ECACE.2019.8679288.

Ahmed, N., Chowdhury, S.S., Tanim, M.F., Ahammed, D.T., Raihan, M.A., Hossain, M., 2024. Safety risk of nonmotorized vehicles from the perspective of motorized vehicle drivers. *Transp. Res. Rec.* 2678 (6), 738–751. https://doi.org/10.1177/03611981231198839/ASSET/IMAGES/LARGE/10.1177_03611981231198839-FIG1.JPEG.

Akomolafe, B., Clarke, A., & Ayambire, R. (2024). Climate change mitigation perspectives from Sub-Saharan Africa: The technical pathways to deep decarbonization at the city level. *Atmosphere 2024, 15*(10), 1190. Doi: 10.3390/ATMOS15101190.

Asadi, S., Nilashi, M., Iranmanesh, M., Ghobakhloo, M., Samad, S., Alghamdi, A., Almulihi, A., Mohd, S., 2022. Drivers and barriers of electric vehicle usage in Malaysia: a DEMATEL approach. *Resour. Conserv. Recycl.* 177 (October 2021), 105965. https://doi.org/10.1016/j.resconrec.2021.105965.

Auspurg, K., Schneck, A., Thiel, F., 2020. Different samples, different results? How sampling techniques affect the results of field experiments on ethnic discrimination. *Res. Soc. Stratif. Mob.* 65, 100444. https://doi.org/10.1016/J.RSSM.2019.100444.

Axsen, J., Cairns, J., Dusyk, N., Goldberg, S., 2018. What drives the Pioneers? Applying lifestyle theory to early electric vehicle buyers in Canada. *Energy Res. Soc. Sci.* 44, 17–30. https://doi.org/10.1016/j.erss.2018.04.015.

Axsen, J., Plötz, P., Wolinetz, M., 2020. Crafting strong, integrated policy mixes for deep CO2 mitigation in road transport. *Nat. Clim. Chang.* 10 (9), 809–818. https://doi.org/10.1038/S41558-020-0877-Y/FIGURES/4.

Bagaini, A., Colelli, F., Croci, E., Molteni, T., 2020. Assessing the relevance of barriers to energy efficiency implementation in the building and transport sectors in eight European countries. *Electr. J.* 33 (8), 106820. https://doi.org/10.1016/J.TEJ.2020.106820.

Balci, G., Phan, T.T.N., Surucu-Balci, E., Iris, Ç., 2024. A roadmap to alternative fuels for decarbonising shipping: The case of green ammonia. *Res. Transp. Bus. Manag.* 53, 101100. https://doi.org/10.1016/J.RTBM.2024.101100.

Bangladesh Road Transport Authority. (2020). Number of Registered Motor Vehicles in Bangladesh (Yearwise). *Bangladesh Road Transport Authority*, *1*, 1.

Bangladesh Road Transport Authority. (2023a). *Number-of-registered-Vehicles-in-Whole-BD - BRTA*. http://www.brta.gov.bd/site/page/74b2a5c3-60cb-4d3c-a699-e2988fed84b2/Number-of-registered-Vehicles-in-Whole-BD.

Bangladesh Road Transport Authority. (2023b). *Number-of-registered-Vehicles-in-Whole-BD - BRTA*. http://www.brta.gov.bd/site/page/74b2a5c3-60cb-4d3c-a699-e2988fed84b2/Number-of-registered-Vehicles-in-Whole-BD.

Bangladesh Road Transport Authority. (2024). *Electric Vehicle Registration and Usage Policy 2024*.

Beccarello, M., Di Foggia, G., 2023. Review and perspectives of key decarbonization drivers to 2030. *Energies* 16 (3). https://doi.org/10.3390/en16031345.

Biresselioglu, M.E., Demirbag Kaplan, M., Yilmaz, B.K., 2018. Electric mobility in Europe: A comprehensive review of motivators and barriers in decision making processes. *Transp. Res. A Policy Pract.* 109, 1–13. https://doi.org/10.1016/J.TRA.2018.01.017.

Boudet, H., Zanocco, C., Stelmach, G., Muttaqee, M., Flora, J., 2021. Public preferences for five electricity grid decarbonization policies in California. *Rev. Policy Res.* 38 (5), 510–528. https://doi.org/10.1111/ropr.12442.

Brant, J.M., Haas-Haseman, M.L., Wei, S.H., Wickham, R., Ponto, J., 2015. Understanding and evaluating survey research. *J. Adv. Pract. Oncol.* 6 (2), 168. https://doi.org/10.6004/jadpro.2015.6.2.9.

Brenner, P. S. (Ed.). (2020). *Understanding Survey Methodology*. *4*. Doi: 10.1007/978-3-030-47256-6.

Briand, Y., Pye, S., D'Agosto, M.d.A., Neves, Goes G.V., Schmitz-Gonçalves, D., Garg, A., Gupta, D., Vishwanathan, S.S., Siagian, U.W.R., Ahjum, F., Trollip, H., 2023. Passenger transport decarbonization in emerging economies: policy lessons from modelling long-term deep decarbonization pathways. *Clim. Pol.* 1–21. https://doi.org/10.1080/14693062.2023.2194859.

Bu, C., Cui, X., Li, R., Li, J., Zhang, Y., Wang, C., Cai, W., 2021. Achieving net-zero emissions in China's passenger transport sector through regionally tailored mitigation strategies. *Appl. Energy* 284, 116265. https://doi.org/10.1016/J.APENERGY.2020.116265.

Bullock, S., Hoolohan, C., Larkin, A., 2023. Accelerating shipping decarbonisation: A case study on UK shore power. *Heliyon* 9 (7), e17475. https://doi.org/10.1016/J.HELIYON.2023.E17475.

CR, AM, CV, 2019. Reducing the environmental pollution from diesel engine fuelled with eco-friendly biodiesel blends. *Bull. Sci. Res.* 35–44. https://doi.org/10.34256/BSR1925.

Cairns-Lee, H., Lawley, J., & Tosey, P. (2021). Enhancing researcher reflexivity about the influence of leading questions in interviews. *Doi: 10.1177/00218863211037446*, *58*(1), 164–188. Doi: 10.1177/00218863211037446.

Cantarella, H., Leal Silva, J.F., Nogueira, L.A.H., Maciel Filho, R., Rossetto, R., Ekbom, T., Souza, G.M., Mueller-Langer, F., 2023. Biofuel technologies: Lessons learned and pathways to decarbonization. *GCB Bioenergy* 15 (10), 1190–1203. https://doi.org/10.1111/GCBB.13091.

Cantarero, M.M.V., 2019. Decarbonizing the transport sector: The promethean responsibility of Nicaragua. *J. Environ. Manage.* 245, 311–321. https://doi.org/10.1016/J.JENVMAN.2019.05.109.

Chen, X., Jia, Y., 2021. Sustainable traffic management and control system for arterial with contraflow left-turn lanes. *J. Clean. Prod.* 280, 124256. https://doi.org/10.1016/J.JCLEPRO.2020.124256.

Christmann, A., Van Aelst, S., 2006. Robust estimation of Cronbach's alpha. *J. Multivar. Anal.* 97 (7), 1660–1674. https://doi.org/10.1016/J.JMVA.2005.05.012.

Cortina, J.M., 1993. What is coefficient alpha? An examination of theory and applications. *J. Appl. Psychol.* 78 (1), 98–104. https://doi.org/10.1037/0021-9010.78.1.98.

Creutzig, F., Jochem, P., Edelenbosch, O.Y., Mattauch, L., Van Vuuren, D.P., McCollum, D., Minx, J., 2015. Transport: A roadblock to climate change mitigation? *Science* 350 (6263), 911–912. https://doi.org/10.1126/SCIENCE.AAC8033/SUPPL_FILE/AAC8033_CREUTIZIG-SM.PDF.

Creutzig, F., Mühlhoff, R., Römer, J., 2012. Decarbonizing urban transport in European cities: four cases show possibly high co-benefits. *Environ. Res. Lett.* 7 (4), 044042. https://doi.org/10.1088/1748-9326/7/4/044042.

Danielis, R., Scorrano, M., Giansoldati, M., 2022. Decarbonising transport in Europe: Trends, goals, policies and passenger car scenarios. *Res. Transp. Econ.* 91, 101068. https://doi.org/10.1016/J.RETREC.2021.101068.

Das, S., Boruah, A., Banerjee, A., Raoniar, R., Nama, S., Maurya, A.K., 2021. Impact of COVID-19: A radical modal shift from public to private transport mode. *Transp. Policy* 109, 1–11. https://doi.org/10.1016/J.TRANPOL.2021.05.005.

de Blas, I., Mediavilla, M., Capellán-Pérez, I., Duce, C., 2020. The limits of transport decarbonization under the current growth paradigm. *Energ. Strat. Rev.* 32, 100543. https://doi.org/10.1016/J.ESR.2020.100543.

de Saxe, C., Lindsay, C., Subramanian, S.C., van Eeden, J., 2023. Decarbonising freight transport: Transitions towards net zero. *Res. Transp. Bus. Manag.* 48, 100984. https://doi.org/10.1016/J.RTBM.2023.100984.

Di Foggia, G., 2021. Drivers and challenges of electric vehicles integration in corporate fleet: An empirical survey. *Res. Transp. Bus. Manag.* 41, 100627. https://doi.org/10.1016/J.RTBM.2021.100627.

DMTCL, 2022. *Electric Vehicle Charging Guideline*. https://dmtcl.portal.gov.bd/site/notices/d860b2ac-5140-4567-980a-11829b879e63/Electric-vehicle-charging-guidelines.

Dolge, K., Barisa, A., Kirsanovs, V., Blumberga, D., 2023. The status quo of the EU transport sector: Cross-country indicator-based comparison and policy evaluation. *Appl. Energy* 334, 120700. https://doi.org/10.1016/J.APENERGY.2023.120700.

Dorian, J. P. ., & Fesharaki, Fereidun. (2019). *Overcoming Barriers to Energy Efficiency in Transportation: The Case of Brazil*. 85–102. Doi: 10.4324/9780429041563-9.

Dyrhauge, H., 2021. Discourses about EU transport decarbonisation: towards a paradigm shift? *Int. Spect.* 56 (3), 71–86. https://doi.org/10.1080/03932729.2021.1962665.

Egbue, O., Long, S., 2012. Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy* 48, 717–729. https://doi.org/10.1016/J.ENPOL.2012.06.009.

Ehsani, M., Singh, K.V., Bansal, H.O., Mehrjardi, R.T., 2021. State of the art and trends in electric and hybrid electric vehicles. *Proc. IEEE* 109 (6), 967–984. https://doi.org/10.1109/JPROC.2021.3072788.

Emodi, N.V., Okereke, C., Abam, F.I., Diemuodeke, O.E., Owebor, K., Nnamani, U.A., 2022. Transport sector decarbonisation in the Global South: A systematic literature review. *Energ. Strat. Rev.* 43, 100925. https://doi.org/10.1016/J.ESR.2022.100925.

Ericsson, K. A. (2006). The Influence of Experience and Deliberate Practice on the Development of Superior Expert Performance. *The Cambridge Handbook of Expertise and Expert Performance*, 683–704. Doi: 10.1017/CBO9780511816796.038.

Everitt, B. S., Landau, S., Leese, M., & Stahl, D. (2011). Cluster analysis: Fifth edition. *Cluster Analysis: Fifth Edition*, 1–330. Doi: 10.1002/9780470977811.

Feng, C., Wang, M., 2018. Analysis of energy efficiency in China's transportation sector. *Renew. Sustain. Energy Rev.* 94, 565–575. https://doi.org/10.1016/J.RSER.2018.06.037.

Gable, G.G., 1994. Integrating case study and survey research methods: an example in information systems. *Eur. J. Inf. Syst.* 3 (2), 112–126. https://doi.org/10.1057/EJIS.1994.12.

Gasparatos, A., Von Maltitz, G.P., Johnson, F.X., Lee, L., Mathai, M., Puppim De Oliveira, J.A., Willis, K.J., 2015. Biofuels in sub-Sahara Africa: Drivers, impacts and priority policy areas. *Renew. Sustain. Energy Rev.* 45, 879–901. https://doi.org/10.1016/J.RSER.2015.02.006.

Gautam, A., Chamoli, S., Kumar, A., Singh, S., 2017. A review on technical improvements, economic feasibility and world scenario of solar water heating system. *Renew. Sustain. Energy Rev.* 68, 541–562. https://doi.org/10.1016/j.rser.2016.09.104.

Ghaforian Masodzadeh, P., Ölçer, A.I., Ballini, F., Christodoulou, A., 2022. A review on barriers to and solutions for shipping decarbonization: What could be the best policy approach for shipping decarbonization? *Mar. Pollut. Bull.* 184, 114008. https://doi.org/10.1016/J.MARPOLBUL.2022.114008.

Gillingham, K., Sweeney, J., 2012. Barriers to implementing low-carbon technologies. *Climate Change Econ.* 3 (4). https://doi.org/10.1142/S2010007812500194.

Gleeson, B., Curtis, C., Low, N., 2003. Barriers to sustainable transport in australia. *Making Urban Transp. Sustainable* 201–220. https://doi.org/10.1057/9780230523838_12.

Globisch, J., Dütschke, E., Wietschel, M., 2018. Adoption of electric vehicles in commercial fleets: Why do car pool managers campaign for BEV procurement? *Transp. Res. Part D: Transp. Environ.* 64, 122–133. https://doi.org/10.1016/J.TRD.2017.10.010.

Godínez-Zamora, G., Victor-Gallardo, L., Angulo-Paniagua, J., Ramos, E., Howells, M., Usher, W., De León, F., Meza, A., Quirós-Tortós, J., 2020. Decarbonising the transport and energy sectors: Technical feasibility and socioeconomic impacts in Costa Rica. *Energ. Strat. Rev.* 32, 100573. https://doi.org/10.1016/J.ESR.2020.100573.

Goel, S., Sharma, R., Rathore, A.K., 2021. A review on barrier and challenges of electric vehicle in India and vehicle to grid optimisation. *Transp. Eng.* 4 (January). https://doi.org/10.1016/j.treng.2021.100057.

Gonçalves, D. N. S., Goes, G. V., D'Agosto, M. de A., & La Rovere, E. L. (2022). Development of policy-relevant dialogues on barriers and enablers for the transition to low-carbon mobility in Brazil. *Sustainability 2022, 14*(24), 16405. Doi: 10.3390/SU142416405.

Gouda, A.A., Masoumi, H.E., 2017. Sustainable transportation according to certification systems: A viability analysis based on neighborhood size and context relevance. *Environ. Impact Assess. Rev.* 63, 147–159. https://doi.org/10.1016/J.EIAR.2016.10.005.

Gray, N., McDonagh, S., O'Shea, R., Smyth, B., Murphy, J.D., 2021. Decarbonising ships, planes and trucks: An analysis of suitable low-carbon fuels for the maritime, aviation and haulage sectors. *Adv. Appl. Energy* 1, 100008. https://doi.org/10.1016/J.ADAPEN.2021.100008.
Guno, C.S., Collera, A.A., Agaton, C.B., 2021. Barriers and drivers of transition to sustainable public transport in the Philippines. *World Electric Vehicle Journal* 12 (1), 1–22. https://doi.org/10.3390/wevj12010046.
Haasz, T., Gómez Vilchez, J.J., Kunze, R., Deane, P., Fraboulet, D., Fahl, U., Mulholland, E., 2018. Perspectives on decarbonizing the transport sector in the EU-28. *Energ. Strat. Rev.* 20, 124–132. https://doi.org/10.1016/J.ESR.2017.12.007.
Haddadian, G., Khodayar, M., Shahidehpour, M., 2015. Accelerating the global adoption of electric vehicles: barriers and drivers. *Electr. J.* 28 (10), 53–68. https://doi.org/10.1016/J.TEJ.2015.11.011.
Hafner, R.J., Walker, I., Verplanken, B., 2017. Image, not environmentalism: A qualitative exploration of factors influencing vehicle purchasing decisions. *Transp. Res. A Policy Pract.* 97, 89–105. https://doi.org/10.1016/j.tra.2017.01.012.
Hainsch, K., 2023. Identifying policy areas for the transition of the transportation sector. *Energy Policy* 178, 113591. https://doi.org/10.1016/J.ENPOL.2023.113591.
Harahap, F., Nurdiawati, A., Conti, D., Leduc, S., Urban, F., 2023. Renewable marine fuel production for decarbonised maritime shipping: Pathways, policy measures and transition dynamics. *J. Clean. Prod.* 415, 137906. https://doi.org/10.1016/J.JCLEPRO.2023.137906.
Hardman, S., Chandan, A., Tal, G., Turrentine, T., 2017. The effectiveness of financial purchase incentives for battery electric vehicles – A review of the evidence. *Renew. Sustain. Energy Rev.* 80, 1100–1111. https://doi.org/10.1016/J.RSER.2017.05.255.
Hasan, A.S.M.M., Kabir, M.A., Hoq, M.T., Johansson, M.T., Thollander, P., 2022. Drivers and barriers to the implementation of biogas technologies in Bangladesh. *Biofuels* 13 (5), 643–655. https://doi.org/10.1080/17597269.2020.1841362.
Hewitt, N. J. (2024). Decarbonizing energy of a city: Identifying barriers and pathways. *Energies 2024, 17*(1), 267. Doi: 10.3390/EN17010267.
Hossain, M. J. Al, Hasan, M. Z., Hasanuzzaman, M., Khan, M. Z. R., & Ahsan Habib, M. (2022). Affordable electric three-wheeler in Bangladesh: prospects, challenges, and sustainable solutions. *Sustainability 2023, Vol. 15, Page 149*, *15*(1), 149. Doi: 10.3390/SU15010149.
Hossain, I., Gülen, G., 2007. Lifecycle analysis of different urban transport options for Bangladesh. *Energy Policy* 35 (10), 4909–4918. https://doi.org/10.1016/j.enpol.2007.04.036.
Hossain, M.A., Chen, S., Khan, A.G., 2021. Decomposition study of energy-related CO2 emissions from Bangladesh's transport sector development. *Environ. Sci. Pollut. Res.* 28 (4), 4676–4690. https://doi.org/10.1007/s11356-020-10846-5.
Hu, C., Youn, B.D., Wang, P., 2019. Statistical data analysis. *Springer Series in Reliability Engineering* 53–81. https://doi.org/10.1007/978-3-319-92574-5_3/TABLES/9.
Huo, D., Davies, B., Li, J., Alzaghrini, N., Sun, X., Meng, F., Abdul-Manan, A.F.N., McKechnie, J., Posen, I.D., MacLean, H.L., 2024. How do we decarbonize one billion vehicles by 2050? Insights from a comparative life cycle assessment of electrifying light-duty vehicle fleets in the United States, China, and the United Kingdom. *Energy Policy* 195, 114390. https://doi.org/10.1016/J.ENPOL.2024.114390.
Imran, M., Pearce, J., 2015. Discursive Barriers to sustainable transport in New Zealand Cities. *Urban Policy Res.* 33 (4), 392–415. https://doi.org/10.1080/08111146.2014.980400.
International Energy Agency. (2022). *Transport - Energy System - IEA*. https://www.iea.org/energy-system/transport.
Jacquemin, J., Thiran, P., Quoilin, S., 2025. Prioritizing the role of renewable fuels and hydrogen networks in the transition towards net zero emissions in Western Europe. *Energy* 314, 134069. https://doi.org/10.1016/J.ENERGY.2024.134069.
Jelti, F., Allouhi, A., & Tabet Aoul, K. A. (2023). Transition paths towards a sustainable transportation system: A literature review. *Sustainability 2023, Vol. 15, Page 15457*, *15*(21), 15457. Doi: 10.3390/SU152115457.
Jenn, A., Springel, K., Gopal, A.R., 2018. Effectiveness of electric vehicle incentives in the United States. *Energy Policy* 119, 349–356. https://doi.org/10.1016/J.ENPOL.2018.04.065.
Jones, T. L., Baxter, M., & Khanduja, V. (2015). A quick guide to survey research. *Doi: 10.1308/003588413X13511609956372*, *95*(1), 5–7.
Kaiser, N., & Barstow, C. K. (2022). Rural transportation infrastructure in low- and middle-income countries: A review of impacts, implications, and interventions. *Sustainability 2022, 14*(4), 2149. Doi: 10.3390/SU14042149.
Kamali Saraji, M., Streimikiene, D., 2023. Challenges to the low carbon energy transition: a systematic literature review and research agenda. *Energ. Strat. Rev.* 49, 101163. https://doi.org/10.1016/J.ESR.2023.101163.
Karmaker, A.K., Hossain, M.A., Kumar, N.M., Jagadeesan, V., Jayakumar, A., Ray, B., 2020. Analysis of using biogas resources for electric vehicle charging in Bangladesh: A techno-economic-environmental perspective. *Sustainability (switzerland)* 12 (7), 1–19. https://doi.org/10.3390/su12072579.
Khan, T. A., & Aziz, T. (2022). Developing A day-ahead dynamic pricing scheme for charging electric vehicles in Bangladesh. *2022 International Conference on Green Energy, Computing and Sustainable Technology, GECOST 2022*, 440–445. Doi: 10.1109/GECOST55694.2022.10010568.
Khatiwada, D., Vasudevan, R.A., Santos, B.H., 2022. Decarbonization of natural gas systems in the EU – Costs, barriers, and constraints of hydrogen production with a case study in Portugal. *Renew. Sustain. Energy Rev.* 168, 112775. https://doi.org/10.1016/J.RSER.2022.112775.
Khuda, K.E., 2020. Air pollution in the capital city of Bangladesh: Its causes and impacts on human health. *Pollution* 6 (4), 737–750. https://doi.org/10.22059/POLL.2020.300588.775.
Khurshid, A., Khan, K., Chen, Y., Cifuentes-Faura, J., 2023a. Do green transport and mitigation technologies drive OECD countries to sustainable path? *Transp. Res. Part D: Transp. Environ.* 118, 103669. https://doi.org/10.1016/J.TRD.2023.103669.
Khurshid, A., Khan, K., Saleem, S.F., Cifuentes-Faura, J., Cantemir Calin, A., 2023b. Driving towards a sustainable future: Transport sector innovation, climate change and social welfare. *J. Clean. Prod.* 427, 139250. https://doi.org/10.1016/J.JCLEPRO.2023.139250.
Kim, Y.G., Lim, H., Lee, J., 2024. Decarbonizing road transport in Korea: Role of electric vehicle transition policies. *Transp. Res. Part D: Transp. Environ.* 128, 104084. https://doi.org/10.1016/J.TRD.2024.104084.
Kinsella, L., Stefaniec, A., Foley, A., Caulfield, B., 2023. Pathways to decarbonising the transport sector: The impacts of electrifying taxi fleets. *Renew. Sustain. Energy Rev.* 174, 113160. https://doi.org/10.1016/J.RSER.2023.113160.
Kłos, M. J., & Sierpiński, G. (2021). Building a model of integration of urban sharing and public transport services. *Sustainability 2021, Vol. 13, Page 3086*, *13*(6), 3086. Doi: 10.3390/SU13063086.
Krishna, G., 2021. Understanding and identifying barriers to electric vehicle adoption through thematic analysis. *Transp. Res. Interdiscip. Perspect.* 10, 100364. https://doi.org/10.1016/J.TRIP.2021.100364.
Kruger, J., Dunning, D., 1999. Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. *J. Pers. Soc. Psychol.* 77 (6), 1121–1134. https://doi.org/10.1037/0022-3514.77.6.1121.
Kuo, T. C., Shen, Y. S., Sriwattana, N., & Yeh, R. H. (2022). Toward net-zero: the barrier analysis of electric vehicle adoption and transition using ANP and DEMATEL. *Processes 2022, Vol. 10, Page 2334*, *10*(11), 2334. Doi: 10.3390/PR10112334.
Kwilinski, A., Lyulyov, O., Pimonenko, T., 2024. Reducing transport sector CO2 emissions patterns: environmental technologies and renewable energy. *J. Open Innov.: Technol., Market, and Complexity* 10 (1), 100217. https://doi.org/10.1016/J.JOITMC.2024.100217.
Laguipo, J., Forde, C., Carton, J.G., 2022. Enabling the scale up of green hydrogen in Ireland by decarbonising the haulage sector. *Int. J. Hydrogen Energy* 47 (63), 26812–26826. https://doi.org/10.1016/J.IJHYDENE.2022.06.053.
Lah, O., 2017. Decarbonizing the transportation sector: policy options, synergies, and institutions to deliver on a low-carbon stabilization pathway. *Wiley Interdiscip. Rev.: Energy Environ.* 6 (6), e257.
LaMonaca, S., Ryan, L., 2022. The state of play in electric vehicle charging services – a review of infrastructure provision, players, and policies. *Renew. Sustain. Energy Rev.* 154, 111733. https://doi.org/10.1016/J.RSER.2021.111733.
Langbroek, J.H.M., Franklin, J.P., Susilo, Y.O., 2016. The effect of policy incentives on electric vehicle adoption. *Energy Policy* 94, 94–103. https://doi.org/10.1016/J.ENPOL.2016.03.050.
Lathia, R., Dadhaniya, S., 2019. Policy norms and proposed ways to achieve goals of Indian vehicle emission program. *J. Clean. Prod.* 208, 1339–1346. https://doi.org/10.1016/j.jclepro.2018.10.202.

Lau, H.C., 2022. Evaluation of decarbonization technologies for ASEAN countries via an integrated assessment tool. *Sustainability (switzerland)* 14 (10). https://doi.org/10.3390/su14105827.
Lee, H., Kim, J., Seo, S., Sim, M., Kim, J., 2022. Exploring behaviors and satisfaction of micro-electric vehicle sharing service users: evidence from a demonstration project in Jeju Island, South Korea. *Sustainable Cit. Soc.* 79, 103673. https://doi.org/10.1016/J.SCS.2022.103673.
Lefèvre, J., Briand, Y., Pye, S., Tovilla, J., Li, F., Oshiro, K., Waisman, H., Cayla, J.M., Zhang, R., 2021. A pathway design framework for sectoral deep decarbonization: the case of passenger transportation. *Clim. Pol.* 21 (1), 93–106. https://doi.org/10.1080/14693062.2020.1804817.
Li, S., Wang, B., Zhou, H., 2024. Decarbonizing passenger transportation in developing countries: Lessons and perspectives1. *Reg. Sci. Urban Econ.* 107, 103977. https://doi.org/10.1016/J.REGSCIURBECO.2024.103977.
Li, S., Zhao, P., Gu, C., Li, J., Cheng, S., Xu, M., 2023. Battery protective electric vehicle charging management in renewable energy system. *IEEE Trans. Ind. Inf.* 19 (2), 1312–1321. https://doi.org/10.1109/TII.2022.3184398.
Loo, B.P.Y., Li, L., Namdeo, A., 2023. Reducing road transport emissions for climate policy in China and India. *Transp. Res. Part D: Transp. Environ.* 122, 103895. https://doi.org/10.1016/J.TRD.2023.103895.
Lu, C., Adger, W.N., Morrissey, K., Zhang, S., Venevsky, S., Yin, H., Sun, T., Song, X., Wu, C., Dou, X., Zhu, B., Liu, Z., 2022. Scenarios of demographic distributional aspects of health co-benefits from decarbonising urban transport. *Lancet Planet. Health* 6 (6), e461–e474. https://doi.org/10.1016/S2542-5196(22)00089-4.
Maestre, V.M., Ortiz, A., Ortiz, I., 2023. Decarbonizing the Spanish transportation sector by 2050: Design and techno-economic assessment of the hydrogen generation and supply chain. *Int. J. Hydrogen Energy* 48 (99), 39514–39530. https://doi.org/10.1016/j.ijhydene.2023.05.154.
Matheus, T.T., Farrapo, A.C., Lagunes, R.M., Filleti, R., Garcia, D.P., Lopes Silva, D.A., 2024. The effect of transportation choices for mitigating climate-related impacts: The case of solid biofuels exported to Europe produced by Latin American countries. *Sustainable Prod. Consumption* 45, 551–566. https://doi.org/10.1016/J.SPC.2024.01.022.
Meckling, J., Sterner, T., & Wagner, G. (2017). Policy sequencing toward decarbonization. *Nature Energy 2*(12), 918–922. Doi: 10.1038/s41560-017-0025-8.
Meyer, T., 2020. Decarbonizing road freight transportation – A bibliometric and network analysis. *Transp. Res. Part D: Transp. Environ.* 89, 102619. https://doi.org/10.1016/J.TRD.2020.102619.
MOEF, 2021. *Nationally Determined Contributions 2021 (NDC)*.
Ministry of Industries, G. (2024). *"Policies" in Ministry of Industries - Government of the People's Republic of Bangladesh.* https://moind.portal.gov.bd/site/view/policies/.
Mohammadi, F., Saif, M., 2023. A comprehensive overview of electric vehicle batteries market. *E-Prime - Advances in Electrical Engineering, Electronics and Energy* 3 (February), 100127. https://doi.org/10.1016/j.prime.2023.100127.
More, K.S., Wolkersdorfer, C., 2024. Exploring advanced statistical data analysis techniques for interpolating missing observations and detecting anomalies in mining influenced water Data. *ACS ES and T Water* 4 (3), 1036–1045. https://doi.org/10.1021/ACSESTWATER.3C00163/ASSET/IMAGES/LARGE/EW3C00163_0006.JPEG.
Mujib Climate Prosperity Plan. (2022). https://mujibplan.com/#.
Murugan, M., Marisamynathan, S., 2022. Case Studies on Transport Policy Analysis of barriers to adopt electric vehicles in India using fuzzy DEMATEL and Relative importance Index approaches. *Case Stud. Transport Policy* 10 (2), 795–810. https://doi.org/10.1016/j.cstp.2022.02.007.
Muzir, N. A. Q., Mojumder, M. R. H., Hasanuzzaman, M., & Selvaraj, J. (2022). Challenges of electric vehicles and their prospects in Malaysia: A comprehensive review. *Sustainability 2022, Vol. 14, Page 8320*, *14*(14), 8320. Doi: 10.3390/SU14148320.
Nagaj, R., Gajdzik, B., Wolniak, R., Grebski, W.W., 2024. The impact of deep decarbonization policy on the level of greenhouse gas emissions in the European Union. *Energies* 17 (5). https://doi.org/10.3390/en17051245.
Nakorji, M., Saleh, A., Wilfred, M., Akadiri, S., 2023. Driving decarbonisation in transport sector: pathways and policies for road transport. *SSRN Electron. J.* https://doi.org/10.2139/SSRN.4660366.
Nardi, P. M. . (2018). *Doing survey research : a guide to quantitative methods*. 260.
Noel, L., Zarazua de Rubens, G., Kester, J., Sovacool, B.K., 2020. Understanding the socio-technical nexus of Nordic electric vehicle (EV) barriers: A qualitative discussion of range, price, charging and knowledge. *Energy Policy* 138, 111292. https://doi.org/10.1016/J.ENPOL.2020.111292.
Noussan, M., Hafner, M., & Tagliapietra, S. (2020). *Policies to Decarbonize the Transport Sector*. 71–112. Doi: 10.1007/978-3-030-37966-7_4.
Noussan, M., Negro, V., Prussi, M., Chiaramonti, D., 2024. The potential role of biomethane for the decarbonization of transport: An analysis of 2030 scenarios in Italy. *Appl. Energy* 355, 122322. https://doi.org/10.1016/J.APENERGY.2023.122322.
Ohene, E., Chan, A.P.C., Darko, A., Nani, G., 2023. Navigating toward net zero by 2050: Drivers, barriers, and strategies for net zero carbon buildings in an emerging market. *Build. Environ.* 242, 110472. https://doi.org/10.1016/J.BUILDENV.2023.110472.
Paipa-Sanabria, C. P. ;, Zapata-Cortes, E. ;, Aguirre-Restrepo, J. A. ;, Cheng, E., Liu, J., Camargo-Díaz, C. P., Paipa-Sanabria, E., Andres Zapata-Cortes, J., Aguirre-Restrepo, Y., & Quiñones-Bolaños, E. E. (2022). A Review of Economic Incentives to Promote Decarbonization Alternatives in Maritime and Inland Waterway Transport Modes. *Sustainability 2022, Vol. 14, Page 14405*, *14*(21), 14405. Doi: 10.3390/SU142114405.
Pan, X., Wang, H., Wang, L., Chen, W., 2018. Decarbonization of China's transportation sector: In light of national mitigation toward the Paris Agreement goals. *Energy* 155, 853–864. https://doi.org/10.1016/j.energy.2018.04.144.
Panoutsou, C., Germer, S., Karka, P., Papadokostantakis, S., Kroyan, Y., Wojcieszyk, M., Maniatis, K., Marchand, P., Landalv, I., 2021. Advanced biofuels to decarbonise European transport by 2030: Markets, challenges, and policies that impact their successful market uptake. *Energ. Strat. Rev.* 34, 100633. https://doi.org/10.1016/J.ESR.2021.100633.
Patil, G., Pode, G., Diouf, B., & Pode, R. (2024a). Sustainable decarbonization of road transport: policies, current status, and challenges of electric vehicles. *Sustainability 2024, 16*(18), 8058. Doi: 10.3390/SU16188058.
Patil, G., Pode, G., Diouf, B., & Pode, R. (2024b). Sustainable decarbonization of road transport: policies, current status, and challenges of electric vehicles. *Sustainability 16*(18), 8058. Doi: 10.3390/SU16188058.
Peñasco, C., Anadón, L. D., & Verdolini, E. (2021). Systematic review of the outcomes and trade-offs of ten types of decarbonization policy instruments. *Nat. Clim. Change 11*(3), 257–265. Doi: 10.1038/s41558-020-00971-x.
Perissi, I., Jones, A., 2022. Investigating European union decarbonization strategies: evaluating the pathway to carbon neutrality by 2050. *Sustainability (Switzerland)* 14 (8). https://doi.org/10.3390/su14084728.
Pettersson, T., Jansson, J., & Lindgren, U. (2022). A barrier to sustainable transports? Path dependence and the Swedish tax deduction for commuting. *Doi: 10.1177/00225266221132710*, *44*(1), 79–98.
Pietrzak, K., & Pietrzak, O. (2020). Environmental effects of electromobility in a sustainable urban public transport. *Sustainability 12*(3), 1052. Doi: 10.3390/SU12031052.
Preedakorn, K., Butler, D., & Mehnen, J. (2023). Challenges for the adoption of electric vehicles in Thailand: potential impacts, barriers, and public policy recommendations. *Sustainability 15*(12), 9470. Doi: 10.3390/SU15129470.
Pyra, M. (2023). Simulation of the progress of the decarbonization process in poland's road transport sector. *Energies 16*(12), 4635. Doi: 10.3390/EN16124635.
Qiu, R., Xu, J., Xie, H., Zeng, Z., Lv, C., 2020. Carbon tax incentive policy towards air passenger transport carbon emissions reduction. *Transp. Res. Part D: Transp. Environ.* 85, 102441. https://doi.org/10.1016/J.TRD.2020.102441.
R, Pathak, G., Pratap, D.V., Lakshay, S., 2024. Barriers and drivers for sustainable public transportation in Indian context. *Green Energy Intell Transp.* 3 (1), 100141. https://doi.org/10.1016/J.GEITS.2023.100141.
Rapson, D. S., & Muehlegger, E. (2023). The Economics of Electric Vehicles. *Doi: 10.1086/725484*, *17*(2), 274–294.
Rayner, T., 2021. Taking the slow route to decarbonisation? Developing climate governance for international transport. *Earth Syst. Governance* 8, 100100. https://doi.org/10.1016/J.ESG.2021.100100.
Raza, M.Y., Lin, B., 2023. Future outlook and influencing factors analysis of natural gas consumption in Bangladesh: An economic and policy perspectives. *Energy Policy* 173, 113379. https://doi.org/10.1016/J.ENPOL.2022.113379.

Rogge, K.S., Reichardt, K., 2016. Policy mixes for sustainability transitions: An extended concept and framework for analysis. *Res. Policy* 45 (8), 1620–1635. https://doi.org/10.1016/J.RESPOL.2016.04.004.

Sandaka, B.P., Kumar, J., 2023. Alternative vehicular fuels for environmental decarbonization: A critical review of challenges in using electricity, hydrogen, and biofuels as a sustainable vehicular fuel. *Chem. Eng. J. Adv.* 14 (January), 100442. https://doi.org/10.1016/j.ceja.2022.100442.

Santarromana, R., Mendonça, J., Dias, A.M., 2020. The effectiveness of decarbonizing the passenger transport sector through monetary incentives. *Transp. Res. A Policy Pract.* 138, 442–462. https://doi.org/10.1016/J.TRA.2020.06.020.

Santos, G., 2017. Road transport and CO2 emissions: what are the challenges? *Transp. Policy* 59 (July 2017), 71–74. https://doi.org/10.1016/j.tranpol.2017.06.007.

Santos, G., Behrendt, H., Teytelboym, A., 2010. Part II: Policy instruments for sustainable road transport. *Res. Transp. Econ.* 28 (1), 46–91. https://doi.org/10.1016/J.RETREC.2010.03.002.

Sarda, J., Patel, N., Patel, H., Vaghela, R., Brahma, B., Bhoi, A.K., Barsocchi, P., 2024. A review of the electric vehicle charging technology, impact on grid integration, policy consequences, challenges and future trends. *Energy Rep.* 12, 5671–5692. https://doi.org/10.1016/J.EGYR.2024.11.047.

Seibert, D., Mocanu, T., Österle, I., Matteis, T., Koller, F., 2023. Decarbonizing the German transport sector: Why the 2030 sector targets are likely to be missed. *Transp. Res. Procedia* 72, 2784–2791. https://doi.org/10.1016/J.TRPRO.2023.11.821.

Shah, K.J., Pan, S.Y., Lee, I., Kim, H., You, Z., Zheng, J.M., Chiang, P.C., 2021. Green transportation for sustainability: Review of current barriers, strategies, and innovative technologies. *J. Clean. Prod.* 326, 129392. https://doi.org/10.1016/J.JCLEPRO.2021.129392.

da Silva, T.B., Baptista, P., Santos Silva, C.A., Santos, L., 2022. Assessment of decarbonization alternatives for passenger transportation in Rio de Janeiro, Brazil. *Transp. Res. Part D: Transp. Environ.* 103, 103161. https://doi.org/10.1016/J.TRD.2021.103161.

Singh, A.R., Vishnuram, P., Alagarsamy, S., Bajaj, M., Blazek, V., Damaj, I., Rathore, R.S., Al-Wesabi, F.N., Othman, K.M., 2024. Electric vehicle charging technologies, infrastructure expansion, grid integration strategies, and their role in promoting sustainable e-mobility. *Alex. Eng. J.* 105, 300–330. https://doi.org/10.1016/J.AEJ.2024.06.093.

Speizer, S., Fuhrman, J., Aldrete Lopez, L., George, M., Kyle, P., Monteith, S., & McJeon, H. (2024). Integrated assessment modeling of a zero-emissions global transportation sector. *Nature Commun. 15*(1), 1–15. Doi: 10.1038/s41467-024-48424-9.

Steenberghen, T., López, E., 2008. Overcoming barriers to the implementation of alternative fuels for road transport in Europe. *J. Clean. Prod.* 16 (5), 577–590. https://doi.org/10.1016/J.JCLEPRO.2006.12.001.

Tang, J., McNabola, A., Misstear, B., 2020. The potential impacts of different traffic management strategies on air pollution and public health for a more sustainable city: A modelling case study from Dublin, Ireland. *Sustainable Cit. Soc.* 60, 102229. https://doi.org/10.1016/J.SCS.2020.102229.

Tarei, P.K., Chand, P., Gupta, H., 2021. Barriers to the adoption of electric vehicles: Evidence from India. *J. Clean. Prod.* 291, 125847. https://doi.org/10.1016/J.JCLEPRO.2021.125847.

Thalmann, P., Vielle, M., 2019. Lowering CO2 emissions in the Swiss transport sector. *Swiss J. Econ. Statist.* 155 (1), 1–12. https://doi.org/10.1186/S41937-019-0037-3/FIGURES/5.

Tipton, E., 2013. Stratified sampling using cluster analysis: a sample selection strategy for improved generalizations from experiments. *Eval. Rev.* 37 (2), 109–139. https://doi.org/10.1177/0193841X13516324/ASSET/IMAGES/LARGE/10.1177_0193841X13516324-FIG2.JPEG.

Tipton, E., Hedges, L., Vaden-Kiernan, M., Borman, G., Sullivan, K., Caverly, S., 2014. Sample selection in randomized experiments: a new method using propensity score stratified sampling. *J. Res. Educ. Effect.* 7 (1), 114–135. https://doi.org/10.1080/19345747.2013.831154.

Tomos, B.A.D., Stamford, L., Welfle, A., Larkin, A., 2024. Decarbonising international shipping – a life cycle perspective on alternative fuel options. *Energ. Conver. Manage.* 299, 117848. https://doi.org/10.1016/J.ENCONMAN.2023.117848.

Trianni, A., Cagno, E., Marchesani, F., Spallina, G., 2017. Classification of drivers for industrial energy efficiency and their effect on the barriers affecting the investment decision-making process. *Energ. Effi.* 10 (1), 199–215. https://doi.org/10.1007/S12053-016-9455-6/METRICS.

Tsemekidi Tzeiranaki, S., Economidou, M., Bertoldi, P., Thiel, C., Fontaras, G., Clementi, E.L., De Los, F., Rios, C., 2023. The impact of energy efficiency and decarbonisation policies on the European road transport sector. *Transp. Res. A Policy Pract.* 170 (February), 103623. https://doi.org/10.1016/j.tra.2023.103623.

Tsoi, K.H., Loo, B.P.Y., Banister, D., 2021. "Mind the (Policy-Implementation) Gap": Transport decarbonisation policies and performances of leading global economies (1990–2018). *Glob. Environ. Chang.* 68, 102250. https://doi.org/10.1016/J.GLOENVCHA.2021.102250.

Tuydes-Yaman, H., Dalkic-Melek, G., Chakarova, K., Ozcelik, A.S., 2024. Barriers and opportunities (B&O) for developing low carbon transportation (LCT) policies in Turkey. *J. Transp. Geogr.* 118, 103903. https://doi.org/10.1016/J.JTRANGEO.2024.103903.

Verlinghieri, E., Haines-Doran, T., Marsden, G., Schwanen, T., 2024. The role of funding in the 'performative decarbonisation' of transport in England. *Polit. Geogr.* 109, 103053. https://doi.org/10.1016/J.POLGEO.2024.103053.

Victor-Gallardo, L., Zúñiga, M.R., Quirós-Tortós, J., Jaramillo, M., Vogt-Schilb, A., 2024. Policy options to mitigate the fiscal impact of road transport decarbonization: Application to Costa Rica. *Energy Policy* 185, 113958. https://doi.org/10.1016/J.ENPOL.2023.113958.

Virmani, N., Agarwal, V., Karuppiah, K., Agarwal, S., Raut, R.D., Paul, S.K., 2023. Mitigating barriers to adopting electric vehicles in an emerging economy context. *J. Clean. Prod.* 414, 137557. https://doi.org/10.1016/J.JCLEPRO.2023.137557.

Wang, C., Engels, A., Wang, Z., 2018. Overview of research on China's transition to low-carbon development: the role of cities, technologies, industries and the energy system. *Renew. Sustain. Energy Rev.* 81, 1350–1364. https://doi.org/10.1016/J.RSER.2017.05.099.

Wang, Y., Guo, Q., Yu, Y., 2023. Cooperative pricing for vehicle-traffic-power nexus to support city decarbonization: a federated deep reinforcement learning framework. *IEEE Trans. Ind. Cyber-Phys. Syst.* 1, 182–191. https://doi.org/10.1109/TICPS.2023.3317012.

Yu, Y., Li, S., Sun, H., Taghizadeh-Hesary, F., 2021. Energy carbon emission reduction of China's transportation sector: An input–output approach. *Econ. Anal. Policy* 69, 378–393. https://doi.org/10.1016/j.eap.2020.12.014.

Zailani, S., Iranmanesh, M., Hyun, S. S., & Ali, M. H. (2019). Barriers of biodiesel adoption by transportation companies: A case of Malaysian transportation industry. *Sustainability 2019, Vol. 11, Page 931*, *11*(3), 931. Doi: 10.3390/SU11030931.

Zhang, A., Alvi, M.F., Gong, Y., Wang, J.X., 2022. Overcoming barriers to supply chain decarbonization: case studies of first movers. *Resour. Conserv. Recycl.* 186 (September 2021), 106536. https://doi.org/10.1016/j.resconrec.2022.106536.

Zhang, H., Irfan, M., Ai, F., Al-Aiban, K.M., Abbas, S., 2024. Analyzing barriers to the adoption and development of electric vehicles: A roadmap towards sustainable transportation system. *Renew. Energy* 233, 121136. https://doi.org/10.1016/J.RENENE.2024.121136.

Zhang, L., Bai, W., 2021. Sustainability of crop–based biodiesel for transportation in China: Barrier analysis and life cycle ecological footprint calculations. *Technol. Forecast. Soc. Chang.* 164, 120526. https://doi.org/10.1016/J.TECHFORE.2020.120526.

Zhang, R., Hanaoka, T., Hu, M., Xu, Y., Xue, J., Liu, J., Sun, Q., 2025. Decarbonizing urban transport in Tokyo: Integrated scenarios of behavioral and technological transformations. *Transp. Res. Part D: Transp. Environ.* 139, 104589. https://doi.org/10.1016/J.TRD.2024.104589.