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The Mekong countries' land transport decarbonization and net-zero strategies: A comparative pilot study with the theory of change and text mining approach to policy analysis

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ABSTRACT

Transport decarbonization is essential for reducing global greenhouse gas emissions, particularly in Asia. This pilot study analyzes land transport decarbonization and net-zero strategies in Cambodia, Laos, Myanmar, Thailand, and Vietnam. It employs a novel analytical framework combining the Theory of Change model and quantitative text mining approaches to complementarily address key provisions, approaches, challenges, and implications for policymakers. The key findings are classified into content analysis of the policy documents, socio-economic and financial factors, and environmental impact. On the socio-economic front, the political stability and development stages of countries critically affect the strategic options. For instance, Thailand's high economic status enables Intelligent Transport Systems implementation, and Vietnam's rapid urbanization drives urban transit infrastructure investment. From a financial perspective, the availability of project funds seriously affects the choice set of investments. Chinese investments are evident in Laos, which leads to extensive investments in rail, while Cambodia depends heavily on ODA, leading to donor-driven development and institutional weaknesses. Vietnam's shift towards market-oriented solutions in land transport development necessitates innovative financial schemes as it reduces ODA reliance. Funding sources also affect environmental consequences, as Chinese investments prioritize speedy economic development, while international organizations' investments focus more on social equity and environmental issues. On the environmental agenda, Myanmar's green transport projects seem driven by international pressure, most probably due to its high ODA dependence, rather than domestic policy priorities. Additionally, all five Mekong countries converge towards electric vehicles (EVs) adoption, prioritizing fuel efficiency and low-carbon emissions as well as investment in public infrastructure such as roads and buses. Policymakers in the Mekong region face complex challenges in balancing economic growth with sustainable land transportation goals, necessitating comprehensive strategies that address technological limitations, infrastructure needs, and environmental concerns.

1. Introduction

The transport sector constitutes among the primary contributors to greenhouse gas (GHG), and its emissions grew at an average annual rate of 1.7 % from 1990 to 2022, outpacing all other end-use sectors except for the industry sector (IEA, 2024). In 2023, Asia contributed 40 % of global transport CO_2 emissions, driving two-thirds of the increase since 2010 (Mejia et al., 2024). Among them, road transport dominated emissions in Asia's low- and middle-income countries (LMICs), accounting for 88 % (Mejia et al., 2024). This trend poses significant challenges for decarbonizing the surface transportation sector in the region.

To meet the Paris Agreement goal of net zero by 2050, the transport sector must reduce CO_2 emissions by 3 % annually (IEA, 2024). Given the significant share and outpaced growth in CO_2 emissions, decarbonizing the developing countries' transport sector, such as those in Southeast Asia (SEA), is an essential priority to meet international climate goals and ensure a sustainable future (ITF, 2023; Lindstad et al., 2023). However, there is limited research on comparative regional national policy analysis on green and sustainable land transportation, especially across the SEA region.

This pilot study primarily conducts a comparative governmental

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policy analysis, through the application of a novel analytical framework that integrates Theory of Change (ToC) principles with text mining, to mitigate the research gap highlighting transportation decarbonization challenges, especially in developing countries (Alam et al., 2025). This paper analyzes five countries in the Mekong region: the "Kingdom of Cambodia", "Lao People's Democratic Republic", "Republic of the Union of Myanmar", "Kingdom of Thailand" and the "Socialist Republic of Vietnam". These countries are referred as Cambodia, Laos, Myanmar, Thailand, and Vietnam, respectively, throughout this research. The analysis focuses on surface transportation, such as road and rail, excluding inland waterways and maritime transportation.

The study's significance is to examine and compare these countries' approaches in terms of national actionable policies and contribute insights to the literature on sustainable and decarbonized transportation strategies in developing economies. This methodological proposition also offers a structured and replicable approach for systematically deconstructing and comparing policy documents across diverse national contexts. The value of this approach lies in its potential for broader application, extending beyond the Mekong region to other geographic regions. To note, all of the Southeast Asian countries of Cambodia, Laos, Myanmar, Thailand, and Vietnam have all demonstrated strong commitments to global climate action by ratifying the United Nations Framework Convention on Climate Change (UNFCCC) in the mid-1990s, with Myanmar, Thailand and Vietnam in 1994, and Laos and Cambodia in 1995 (UNTC, 2009). All countries also signed the Paris Agreement in 2016, with Laos, Thailand, and Vietnam ratifying in 2016 itself, while Cambodia and Myanmar ratified in 2017 (UNTC, 2015).

A detailed comparative summary of key national indicators, including population, economic capacity and transport infrastructure data is presented in sections 2.1.1 to 2.1.5 on a country level basis. The findings of this research will not only enhance understanding of regional policy dynamics in the SEA region but also offer lessons for other emerging markets grappling with similar challenges in balancing economic growth with environmental sustainability in the land transportation sector. The research questions (RQs) of this research are as follows:

RQ1: What are the key provisions and strategies for decarbonization and net-zero emissions within the land transportation policies as presented in the selected official policy documents of the Mekong countries?
RQ2: What are the similarities and differences in these approaches across the analyzed policy documents from Cambodia, Laos, Myanmar, Thailand and Vietnam?
RQ3: What challenges and barriers to implementation are identified within the analyzed policy documents of the Mekong countries?

The structure of this research is divided into six sections, including the introduction. Section 2 relates to the literature review and country-specific analysis in the Mekong region. Section 3 explains the research design. Section 4 analyses the research findings while Section 5 refers to the discussion. Section 6 concludes with assessments of the prohibiting factors and its policy implications.

2. Literature review

Decarbonization and net-zero policies in the land transportation industry are distinctive and yet closely interconnected concepts in the pursuit of GHG emissions reduction. Decarbonization focuses on reducing GHG emissions (Wimbadi and Djalante, 2020), while net-zero aims to balance emissions with carbon removal, involving with carbon offsetting measures (Net Zero Climate, 2024). In practice, both strategies often overlap, as achieving net-zero typically requires significant decarbonization efforts (Han et al., 2023).

Decarbonization is reducing carbon emissions by transitioning from fossil fuels to low-carbon or zero-carbon alternatives (IEA, 2023). Electric vehicles (EVs) are an effective solution for reducing carbon emissions by replacing fossil-fuel with electricity, especially from renewable sources. The popularity of EVs in the Mekong region is, however, disputed. EV adoption in SEA is still at its nascent stage and lack a long-term strategy. EVs promotion is often hindered by insufficient quantitative impact assessments, a lack of infrastructure investment, and financing challenges (Li and Chang, 2019). In addition, in developing countries, efforts to reduce carbon emissions are often hampered by factors such as limited technological capabilities, low disposable incomes, and the presence of other developmental priorities that require scarce resources. Furthermore, EVs' cost-effectiveness depends on battery and renewable energy costs, as well as carbon removal deployment (Akimoto, 2023).

Moreover, the complexity of institutional/inter-governmental arrangements makes reaching agreements difficult, especially when directional changes are required (Deakin, 2019). Comprehensive transport decarbonization plans can be ineffective if policy instruments are poorly defined and coordinated among policymakers from different related ministries (such as energy and transportation), or executed by relevant stakeholders (Tsoi et al., 2021). Commitment to net zero, as an extension of decarbonization, is widespread among Asian countries. However, there is 'still a lack of a common understanding of the implications of the net zero transition in the transport sector in Asia' (Gota and Huizenga, 2023), and often there is a lack of clear guidance on how to achieve it (Fankhauser et al., 2022). The Emissions Gap Reports from UNEP (2021) and UNEP (2023) also highlight the difficulties in defining and achieving net zero, which often leads to an over-dependence on carbon removals and unreliable carbon credits (McLaren et al., 2019).

Transport decarbonization is also challenged by hurdles of integrating land use, transportation, and environmental planning (Iseki, 2024). The interplay between transportation and land use in Southeast Asia presents significant challenges to sustainable urban development, the environment and transport decarbonization. In Bangkok, Thailand despite the expansion of mass transit systems like the Bangkok mass transit (BTS) and mass rail transit (MRT), the city's rapid urban growth has led to severe traffic congestion, with private vehicle use remaining high due to inadequate integration of land use and transport planning (Subpawanthanakun, 2024). In Hanoi, Vietnam, the prevalence of informal settlements and narrow alleyways has resulted in a strong reliance on motorbikes, complicating efforts to implement efficient public transportation systems (Nguyen and Turner, 2023). The city of Phnom Penh in Cambodia faces similar issues, with high reliance on motorcycles and private cars and rapid urbanization without effective land-use control, leading to fragmented traffic congestion, pollution, urban growth, and transportation networks (ATO, 2024a).

In Laos, the development of emerging economic corridors, including the China-Laos Railway has led to significant land use and environmental changes (Chanthavong, 2024), whereby it was found in Xiao et al., (2024) that 38 % of rail construction land contributed to forest loss in Laos. Lastly, Gómez-Ibáñez et al. (2012) found that Yangon, Myanmar's largest city, was poorly prepared to cope with the pressures of growth due to the lack of a comprehensive land-use and development plan. This inadequacy hampered the city's ability to manage urban expansion and integrate transport infrastructure effectively. Moreover, due to long-term underinvestment and weak transport governance, Yangon faces severe traffic congestion, prompting calls for solutions like bus rapid transit and cycling to enhance sustainable mobility (Fox et al., 2019).

These illustrate how the lack of integrated planning between land use, transportation, and environmental planning (Iseki, 2024) hampers efforts toward transport decarbonization within Southeast Asian cities. Without coordinated policies, transport infrastructure improvements alone cannot effectively cut emissions, as spatial and regulatory issues persist. Achieving low-carbon mobility in Southeast Asia thus requires integrating land use, transport, and environmental planning within just transition and climate equity transportation frameworks.

Just Transitions and Climate Equity: The panacea in land transport decarbonization challenges in Southeast Asia?

A just transition ensures low-carbon transport shifts are fair and inclusive, while climate equity focuses on distributing decarbonization impacts fairly, and both frameworks are vital for inclusive, context-sensitive land transport decarbonization in Southeast Asia (Ternes et al., 2024; Bruzzone et al., 2023). In Myanmar and Laos, where transport infrastructure remains limited and institutional capacities are weak, decarbonization must address rural connectivity and affordability while safeguarding vulnerable populations (UNESCAP, 2021). In Thailand and Vietnam, rapid urbanization and growing transport emissions call for integrated climate equity strategies that consider social impacts, such as affordability and access to green mobility (World Bank, 2022; IEA, 2022). In Cambodia, where informal modes dominate, a just transition should include training and financial assistance for low-income transport workers adapting to low-carbon technologies (ILO, 2022). Moreover, a climate equity lens helps reconcile historical emissions responsibilities with each country's development stage (Newell and Mulvaney, 2013), ensuring fair burden-sharing.

2.1. Country analysis: sectoral land transportation literature review

2.1.1. Cambodia

Cambodia is a lower-middle-income economy with 16.9 million people (World Bank, 2023). In 2023, Cambodia's GDP per capita was USD 2,430 (World Bank, 2024c) its net official development assistance (ODA) received as a percentage of gross national income (GNI) was 5.5 % in 2020, and its CO_2 emissions reached 14.4 million tons (0.8 metric tons per capita) in 2020 (UN Data, 2024a; UN Data, 2024b). The country views low-carbon development as a mutually beneficial strategy to enhance energy efficiency, promote renewable energy, and sustain social and economic development, thereby avoiding pervasive economic growth (NCGG, 2013). The country has developed several policies and strategies, including the LTSCN policy and the National Strategic Plan on Green Growth (2013–2030). Under the Circular Economy Strategy and Action Plan, priority area 1.3, aims to promote sustainable transportation by leveraging fuel quality regulations and minimizing GHG emissions (Herrador, 2024).

In terms of land transportation, Cambodia's road network spans over 38,000 km, but less than 50 % is paved while rural roads remain underdeveloped and prone to seasonal flooding, limiting rural-urban mobility (ADB, 2019). The construction of road transportation infrastructure has also received much traction, but in practice, there is scant literature on environmental impact assessments for such projects. For instance, no ecological study is found in Cambodia, regarding the Phnom Penh-Sihanoukville Expressway (Zhang et al., 2023). Similarly, Chinese government-financed road projects between 2003 and 2021 in Cambodia are mostly situated in areas with more 'plantations and concessions', leading to significant deforestation (Baehr et al., 2023). Also, the railway network is underutilized and outdated, operating only two main lines with limited frequency and low efficiency (World Bank, 2024). Thus, this calls for better integration of road and rail development with green planning so as to reduce the country's carbon-intensive logistics dependency.

Hak et al. (2017) indicate that Cambodia has the potential to significantly reduce its CO2 emissions. Their projections suggest that with the implementation of countermeasures, Cambodia could decrease its annual CO2 emissions by approximately 5,685 kilotons by 2030 and 25,761 kilotons by 2050. These relate to developing public transport systems in major cities, implementing hybrid and biodiesel motorized vehicles, introducing low-emission and energy-efficient vehicles, and promoting eco-driving practices and vehicle technical inspections (Hak et al., 2017). The majority of Cambodians (94.41 %) expressed that they believe the future of automobiles is in EVs, with a significant presence of a giant Chinese EV manufacturer BYD, planning an EV assembly plant in Cambodia (Chheng, 2024). However, EVs still face challenges: current market domination by imported gasoline and diesel-powered vehicles, the massive investment requirements for charging stations, and the need for policy support to facilitate this transition (Bou, 2024).

2.1.2. Laos

Laos, with a population of 7.7 million, experienced a GDP growth rate of 5.5 %–7.0 % in the late 2010s. In 2023, Laos' GDP per capita was USD 2,067 (World Bank, 2024c), its ODA acceptance as a percentage of GNI was 3.0 % in 2020, and its CO_2 emissions reached 17.42 million tons (2.3 metric tons per capita) in 2020 (UN Data, 2024a; UN Data, 2024b). The economy has been projected to grow by 4 % in 2024, driven by services, foreign investment, and special economic zones (Felsenthal and Glendinning, 2024). Laos is predicted not to achieve net-zero GHG emissions by 2060 (Kyophilavong et al., 2023), and the highest GHG emitting sector in Laos is the transport sector. As of 2018, it was responsible for 73.95 % of total emissions, and by 2060, it is forecasted to still be the leading contributor at 69.01 % (Kyophilavong et al., 2023). Thus, the country must strengthen its national green transport strategies.

In terms of transportation infrastructure, Laos has a 44,000 km road network, but only about 17 % is paved, with poor maintenance and landslide risks in mountainous regions and limited rural access, especially during the rainy season (World Bank, 2020). The country's landlocked status necessitates efficient intermodal connectivity, yet weak institutional capacity hinders effective infrastructure governance (World Bank, 2020). This calls for further strengthening resilience and sustainability in its road-rail systems, as it is crucial for decarbonization and cross-border integration. Furthermore, among the transportation investments, the Lao-China railway has significantly improved accessibility in-country and with Lao's neighbouring countries (Xiao et al., 2024). It has reduced travel time between Vientiane, Lao's capital, to Boten, at China's border from 21-hour bus ride to three to 4-hour by railway (Suhardiman et al., 2021). However, this cross-border mode of transportation has raised concerns about detrimental socio-environmental impacts (Teo et al., 2019), including pollution, deforestation, and loss of biodiversity (Guillaume et al., 2018; Zeng et al., 2018).

E-mobility has also expanded in Laos. Electric bus rapid transit (BRT) systems have been developed and EVs have been adopted as a way to reduce fossil fuel demand, control the trade deficit, and decarbonize the economy (Global Green Growth Institute, 2022; Kimura et al., 2021). Dixon et al. (2023) further mention that transport decarbonization relies on the concurrent electrification of the majority of land transport modes and a substantial increase in renewable electricity generation. Laos has significant potential for renewable energy generation, particularly hydropower, which could facilitate an affordable shift to e-mobility (Erdiwansyah et al., 2019). However, the country lacks collaboration between the transport and energy ministries. This results in a major obstacle to e-mobility and renewable energy integration, creating "unwanted silos" (Dixon et al., 2023) between government departments, that is between energy and transport ministries.

2.1.3. Myanmar

Myanmar, with a population of 54 million, had a modest GDP growth of 6 %–7 % growth in the late 2010s. Its GDP per capita was USD 1,233 as at 2023 (World Bank, 2024c) and a high inflation rate of 15.5 % in 2024 (ADO, 2024). Myanmar's ODA acceptance as a percentage of GNI was 3.8 % in 2020, and its CO_2 emissions reached 34.89 million tons (0.6 metric tons per capita) in 2020 (UN Data, 2024a; UN Data, 2024b). The country has experienced long-lasting military occupation and civil wars. Myanmar was previously liberalized after the general election in 2010, and soon after the liberalization, it initiated actions against climate change. In February 2021, a military coup disrupted the country's democratic transition and socio-economic development (Abb et al., 2024). Such political turmoil deters the country's national development, including the land transportation sector (World Bank, 2024a).

In terms of land transport, Myanmar's road network spans approximately 157,000 km, but only 20 % are paved (Mikou et al., 2019). Rail infrastructure includes 5,400 km of mostly single-track, meter-gauge lines, many in poor condition. Specifically, the "transportation infrastructure lag" includes limited road access for 20 million people, deteriorating highways and railways, and poor infrastructure in the Yangon region affecting logistics (Banomyong and Fernandez, 2021). The lack of institutional capacity and political stability also impedes efforts to upgrade transport systems and implement decarbonization strategies. Empirically, the armed conflicts have damaged critical routes such as National Highway 8, hampering domestic and cross-border transport (Han, 2024). Nevertheless, the Myanmar government developed plans like the National Transport Master Plan, the Urban Transport Development Plan for Greater Yangon, and the National Strategy for Rural Roads and Access (Liu et al., 2023; Htike, 2017). Myanmar has also implemented the Myanmar Climate Change Strategy (The Republic of the Union of Myanmar, 2019), which outlines sector-specific actions to mitigate climate change impact, including the surface transportation sector (Qiu et al., 2024). As reiterated, however, Myanmar's ongoing political instability reinforced significant doubts on the implementation of these plans. Lastly, EV adoption in Myanmar is also rising, primarily fueled by government incentives like zero tariffs on EV imports and components (Li and Chang, 2019), the import of affordable Chinese models (Aye and Htet, 2024), and the military ban on the import of gasoline-powered vehicles (Nikkei Asia, 2024). However, inadequate charging infrastructure and high capital expenditure costs may hinder the widespread use of EVs (Augustin, 2023).

2.1.4. Thailand

Thailand, an upper-middle-income country in SEA, has a population of 70 million. While, in the late 2010s, the GDP growth was around 2 %–4 %, the country's GDP growth stood at 2.4 % in 2024, rising to projected 2.8 % in 2025 (Kongrukgreatiyos, 2024). In 2023, Thailand's GDP per capita was USD 7,182 (World Bank, 2024c), its ODA acceptance as a percentage of GNI was 0.04 % in 2020, and its CO_2 emissions reached 247.94 million tons (3.5 metric tons per capita) in 2020 (UN Data, 2024a; UN Data, 2024b). In terms of transport network, Thailand has a well-maintained road network while rail spans 4,507 km of mostly single-track, meter-gauge lines (OECD, 2018), but upgrades face delays. The Thailand's government has integrated low-carbon transport goals into its 20-Year Transport Strategy and is advancing EV, rail electrification, and modal shift policies (ATO, 2024b).

Thailand aims to lead as the EV hub regionally with the country's target of 30/30, implying that by 2030, 30 % of car manufacturing in-country will be zero-emission vehicles (ESCAP, 2023). A significant EV deployment leads to benefits such as transport energy savings, reduced emissions and pollution (Wattana and Wattana, 2022). Moreover, it enables smart grid integration that supports renewable energy adoption and grid efficiency. The challenges for EV adoption include grid strain, energy security concerns, industry disruption, and increased electricity demand, requiring careful planning and infrastructure development. Better managing of used EV batteries is also needed to maximize resource efficiency and minimize waste in Thailand (Chaianong et al., 2024). Moreover, the "implementation of energy-related environmental policy" is necessary to derive benefits in the energy and transportation sectors, as EV may simply shift GHG emissions from transport to energy sector (Winyuchakrit et al., 2017). Thailand also intends to expand and upgrade its public transportation systems. Thailand has rail systems including the State of Thailand Railway (SRT), the airport rail, and Bangkok's BTS Skytrain (Archarya and Morichi, 2007; Nakamura and Hayashi, 2013). To reduce pollution caused by old public buses, implementing vehicle age limits, enhancing fuel economy, and adopting low-emission alternative fuels are recommended (Lewchalermvongs et al., 2024; Traivivatana et al., 2017).

2.1.5. Vietnam

Vietnam, with a population of about 100 million, with previous GDP growth of 6.5 %–7 % in the late 2010s, experienced a GDP per capita of USD 4,282 (World Bank, 2024c) as of 2023 and the country is rapidly growing (Bugrov et al., 2024; Duc, 2024). Vietnam's ODA acceptance as a percentage of GNI was 0.4 % in 2020, and its CO_2 emissions reached 297.52 million tons (3.0 metric tons per capita) in 2020 (UN Data, 2024a; UN Data, 2024b). In Vietnam, road transport electrification is essential for minimizing air pollution and climate change impact. For instance, replacing conventional buses with electric buses could decrease GHG emissions by 42.62 g of CO2 equivalent per passenger kilometer traveled in Vietnam (Luu et al., 2022). The rise of EV usage, predominantly in cities, has also decreased emissions from the transport sector (Huu and Ngoc, 2021). A study of Ho Chi Minh City residents finds that electric cars and electric motorcycles attracted much interest among local consumers, but EVs also underlined structural barriers such as battery problems and lack of charging infrastructures (Truong et al., 2024).

Railway and road infrastructures are also essential for economic activity and urban functionality (Palei, 2015). As such, Vietnam has a road network exceeding 595,000 km, with expressways accounting for over 2,000 km (Nguyen and Dapice, 2024). The rail network, 3,143 km in length, is outdated and underfunded, lacking interoperability with regional systems (Donski-Lesiuk, 2023). Modernization and clean energy integration into both rail and road systems are necessary for Vietnam's decarbonization pathway. Hanoi's Master Plan to increase the present roads and railways by threefold by 2030 is expected to have environmental implications and local and global climate change impact in terms of increased GHG emissions, intensified resource extraction and land use, waste generation and air and water pollution (Miatto et al., 2021). Nonetheless, construction material shortage is a hurdle to realizing the plan, and recycling is recommended. Overall, Vietnam is politically committed to transport decarbonization, with clear targets under its National Green Growth Strategy and active participation in Just Energy Transition Partnerships (Linh, 2021).

3. Research design

3.1. Research methodology

This research employs a mixed method approach, using content comparative data analysis leveraging, on the Theory of Change (ToR) model and on quantitative text mining approach. The text mining pathway analyzes singular national policy documents from Cambodia, Laos, Myanmar, Thailand (except two documents), and Vietnam individually, as well as collectively as a single corpus. The emerged insights were thereafter categorized into the content and critical analysis based on the ToR model and into three main sub-categories: socio-economic and financial, and environmental for further discussion.

3.2. Data

This research analyses six national policy documents on green land transportation, one for each target country, with an additional document for Thailand due to the broad nature of its primary national policy strategy (Table 1).

The above Southeast Asian countries have adopted green and development strategies through ministerial coordination or cabinet approval. Cambodia, Laos, and Myanmar developed plans via key ministries. Notably, Myanmar's policy document is published during the liberalization period when Aung Sam Suu Kyi was the state counsellor. Thus, the policies presented here were proposed when Myanmar was collaborative with other ASEAN countries (as reflected in Table 8) and international organizations, which may have been discontinued after the military coup. Thailand's strategy was legally adopted by Cabinet and Gazette. Vietnam's green strategy was formalized by Prime Ministerial

Table 1
List of national policy sectoral priorities, focusing on sustainable land transportation.

Country	Policy Document (PD)	PD Ref.	Authority in charge
Cambodia	Long-Term Strategy for Carbon Neutrality December 2021	(i)	National Council for Sustainable Development, Ministry of Environment
Laos	National Green Growth Strategy of the Lao PDR till 2030 2018	(ii)	Secretariat for Formulation of National Green Growth Strategy of the Lao PDR
Myanmar	Myanmar Sustainable Development Plan 2018–2030 August 2018	(iii)	Ministry of Planning and Financed The Government of the Republic of the Union of Myanmar
Thailand	National Strategy 2018–2037 2017	(iv - i)	Office of the National Economic and Social Development Board, National Strategy Secretariat Office
	Thailand's Transport Infrastructure Development Plans (20-year) August 2022	(iv - ii)	Office of Transport and Traffic Policy and Planning
Vietnam	National Green Growth Strategy 2021–2030 with a vision to 2050 October 2021	(v)	Ministry of Planning and Investment

decision, with cross-ministerial implementation and national steering oversight.

3.3. Theory of change model

The Theory of Change (ToC), coined by Weiss (1995) is a methodological framework that articulates how and why a desired change is expected to occur in a specific context. It involves mapping out the logical sequence of events, from inputs and activities to outcomes and impacts, underpinned by explicit assumptions and contextual factors (Lam, 2020). In this comparative policy analysis, particularly focusing on the land transportation sector, as reflected in Appendix A and Flow Diagram 1 in Section 4.1, the ToC serves as a valuable tool for understanding the causal pathways through which transport policies and interventions lead to sustainable outcomes within the Mekong countries under study.

The policy document selection was based on a pre-defined scope of national-level, post-Paris Agreement green policies with focus on transportation. The policy interpretation involved a systematic extraction of all text segments pertaining to the defined land transport modes, which were then categorized into the pre-established ToC components to ensure consistent analysis. Regarding the themes' derivation, it was an iterative and multi-stage process. First, all national policy documents from each country were reviewed in their entirety to establish context. The sections pertaining to the defined transport sectors (excluding air, inland waterways, and maritime) were then isolated for detailed analysis. These text segments were systematically classified into the pre-defined categories of the Theory of Change framework (Inputs, Activities, Outputs, Outcomes, Impact). This framework was applied deductively, meaning it served as the initial, logical structure for organizing the data and assign meanings (Fife and Gossner, 2024). For example, financial resources and policy and regulatory framework supporting green transport were coded as "inputs", while development of charging infrastructure was classified as an "activity", coalescing into the broader theme of "Electric Vehicles Adoption." This iterative process ensured themes were grounded in the data while maintaining its analytical structure.

3.4. Text mining

Text mining uncovers hidden patterns and information, leading to new knowledge and a deeper understanding of complex topics (Shu and Ye, 2022). This research employs WordStat, a text analysis software to assess word frequency, normalized pointwise mutual information (NPMI), eigenvalue, and word clouds to uncover patterns and associations within the data.

The calculation of NPMI is based on the work of Bouma (2009), which corrects the bias in traditional PMI. Pointwise Mutual Information (PMI) is one of the standard association measures for extracting collocation. PMI of x and y $i\ (x, y)$ measures the difference between the probability of co-occurrence of events x and y $p\ (x, y)$ and expected probability based on the probability of individual occurrence and the independence assumption $p(x)p(y)$.

$$i(x,y) = ln\,\frac{p(x,y)}{p(x)p(y)}$$

If the independence assumption holds, PMI is zero because p (x, y) = p(x)p(y). NPMI normalizes PMI as follows:

$$i_n(x,y) = \frac{\left(ln\ ln\ \frac{p(x,y)}{p(x)p(y)}\right)}{-ln\,p(x,y)}$$

When two words perfectly collocate together, $i_n\ (x, y) = 1$, when two words never appear together, $i_n\ (x, y) = -1$, and when these words are independent, $i_n\ (x, y) = 0$. NPMI offers improved topic coherence measurement compared to earlier methods like UMass (Mimno et al., 2011). An NPMI of less than 0.5 implies a weak to moderate association between terms and topics. Eigenvalue computation for topic modeling uses matrix decomposition methods (Deerwester et al., 1990). It indicates the variance explained by a particular factor or component (Jolliffe, 2002), and values greater than 1 are used as retaining criteria (Kaiser, 1960). Eigenvalue-based approaches provide robust topic extraction but may struggle with interpretability.

In this study, "transport" serves as a target word for WordStat topic modeling. The process begins by creating a term-document matrix that includes "transport" and related terms linked to decarbonization and net-zero. A factor analysis is then conducted to extract topics, represented as eigenvectors, that contain "transport". Following this, eigenvalues are calculated for each topic to assess its importance. The software also computes NPMI for the top words associated with "transport" in each topic, leading to an average NPMI score for evaluating topic coherence. A two-stage approach is adopted by the authors: firstly, refining topics through enrichment to identify related phrases like "electric vehicles" and "climate change", which are interconnected with transport decarbonization. Secondly, selecting topics, related to the target word, with high eigenvalues and NPMI scores, such as "promote market" and "urban development". This method enables the researchers to uncover multiple contexts where "transport" appears, accounting for its varied usage in the corpus.

Lastly, frequency analysis, based on the frequency of tokens (Mahgoub et al., 2008), has been conducted and is illustrated through word clouds in this research. Word clouds utilize term frequency-inverse document frequency (TF-IDF) weighting (Salton and Buckley, 1988). Although it risks oversimplifying complex textual relationships, visual presentation helps us understand associations intuitively.

The analysis, in this research, often finds a combination of low NPMI and high eigenvalues. It indicates a high-level theme containing broad and diverse corpus topics. The document is directed toward a specific topic, such as public works and transport, yet individual programs within the topic are diverse, resulting in a weak word-level collocation.

3.5. Practicality and relevance of mixed-methodological innovation approach

The integration of Theory of Change with computational text mining (NPMI, eigenvalue and frequency analysis) offers a novel, practical methodology for systematic policy analysis, in line with Hendren et al., (2023) stating that mixed method research is rising within the public policy domain. This approach transcends standard qualitative comparison by providing scalable, reproducible, and objective identification (Nelson et al., 2021) of not only key policy priorities (via word clouds), but also their semantic relationships (NPMI) and structural importance (eigenvalues) within strategic documents. By mapping these quantitatively derived elements alongside a structured ToC framework, this mixed method approach generates relevant findings. For example, revealing nuances relating to the land transport policies, strategies, goals and regional commitments at country level are indicated in Table 8 while policy implications are discussed in section 6. Thus, this offers policymakers a clear, evidence-based tool for diagnosing gaps and enhancing strategic coherence in decarbonization of land transport planning, especially in the Mekong region.

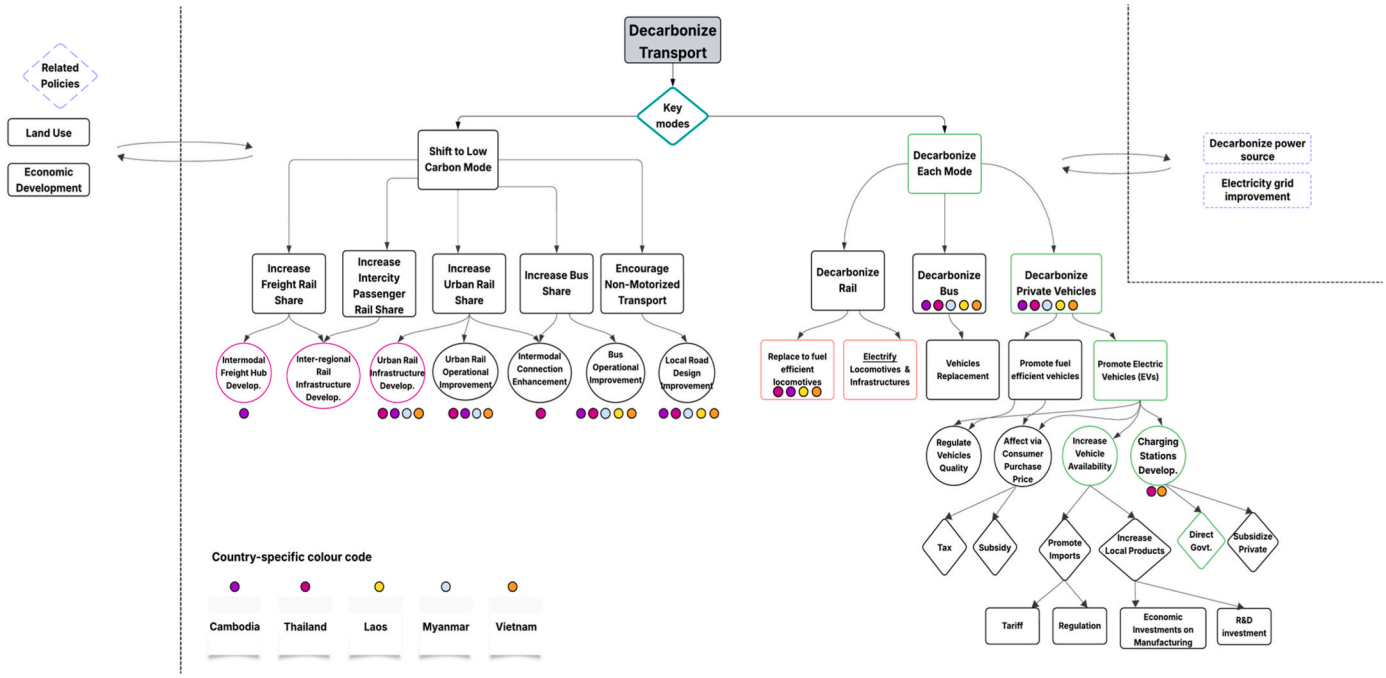
4. Findings

4.1. Theory of change findings

The main transportation-related sections from the national policies from Cambodia, Laos, Myanmar, Thailand, and Vietnam in Table 1 has been systematically reviewed and categorized into inputs, activities, outputs, outcomes and impact using the theory of change model approach and is reflected in Appendix A. This structured approach results in greater clarity in identifying strengths and weaknesses and facilitating cross-country comparisons. This method also provides valuable insights into policy impacts, fostering a deeper understanding of how transportation policies contribute to environmental and economic outcomes, particularly in the context of sustainability and decarbonization efforts.

The five Mekong countries aim to enhance sustainability, reduce emissions, and improve mobility. Cambodia targets carbon neutrality by 2050 focused on rail development, EV adoption, and expanding urban public transport. Laos prioritizes clean-energy electric vehicles and public transit improvements to reduce congestion and boost economic activity. Myanmar's strategy, aligned with SDGs and regional goals, promotes EVs, biofuels, and rural access to support low-carbon, inclusive growth. Thailand advances green infrastructure through public-private partnerships, focusing on rail and EV development to cut pollution and increase competitiveness. Vietnam aims to build a multimodal, energy-efficient transport system powered by clean energy to meet net-zero targets. Collectively, these five countries seek to transition to sustainable, low-carbon transport systems that support economic growth, environmental protection, and improved quality of life.

Transportation decarbonization and net-zero policies in the six policy documents listed in Table 1, together with relevant peripheral topics such as land-use, economic development, electricity grid enhancement, and power sector decarbonization policies, is visually synthesized in Flow Diagram 1. Each country under study is colour-coded and positioned according to the topics where they demonstrate the most pronounced policy focus. Correspondingly, the transportation decarbonization policy documents from the five countries focus on two primary strategies: firstly, shifting to low-carbon modes and secondly, decarbonizing existing transport modes. The first strategy includes increasing the share of freight rail, intercity passenger rail, urban rail, bus usage, and promoting non-motorized transport. All five countries are improving road designs to support non-motorized transport. Urban rail development is also prioritized in all countries with a notable difference for Laos. The latter's government funding seems to be mainly directed toward road infrastructure, while rail development, through the Lao-China Railway, is majoritively Chinese-funded. Bus operational improvements are particularly emphasized in all countries under study, with Thailand also focusing on enhancing intermodal connections and Cambodia on developing intermodal freight hubs. The second strategy centers on decarbonizing bus, and private vehicles, with all five countries promoting electric vehicles (EVs), whereby Thailand and Vietnam are active in developing charging infrastructure.



Flow Diagram 1. Decarbonizing Transport in the Mekong region (Source: Authors, 2024).

4.2. Text mining results: country-level

4.2.1. Cambodia

Cambodia's interests in decarbonizing existing modes are quantitatively confirmed in the text mining analysis. The "operating expenditures and fuel loss" is the most significant and coherent topic associated with transport in Cambodia (Table 2), suggesting that fuel-related operating costs are a major concern for Cambodia's rail and public transportation (Fig. 1 (a)). This suggests that Cambodia's transportation sector is primarily grappling with operational challenges due to low-fuel efficiency fossil-fuel powered vehicles.

For topic 2, "electric vehicles", both Fig. 1(a) and (b) indicate the importance of electrification and EVs in the country. However, the moderate penetration of EVs, 70 % for motorcycles and 40 % for cars and urban buses by 2050 in Cambodia (section 2.1.2 of the document), suggests that EVs is still in its early stages, in line with Chheng (2024). Investment in rail development will begin after 2030 (executive summary), implying that there is infrastructure to be built to sustain its growth (Bou, 2024). Significant but low NPMI of topic 3 "financing plan" indicates that financing is relevant and necessary to realize these ambitious modernization plans, although financial data are not available in the policy document. This is due to only the high-level and concise information available on public financing needs and financing plans (section 2.2.2).

4.2.2. Laos

In Laos, the Ministry of Public Works and Transport works for transportation, urban development and waste management. Thus, public works and transport show NPMI of 0.29 and the eigenvalue of 2.47, while level of coherence at word-level is moderate (Table 3). The word frequency (Fig. 2) with the inclusion of "ministry" and "public" in the keywords, indicates a strong government role in shaping and implementing transport policies and projects, including urban transportation development. The word cloud (Fig. 2), also shows that transport development in Laos is closely tied to various economic sectors, reflecting a comprehensive socio-economic approach to infrastructure planning. These are evidenced by Laos' national policy's motto to pursue a sustainable and resilient economic growth that balances efficiency, inclusivity and adaptability.

4.2.3. Myanmar

Myanmar's policy document discusses climate resilience more than other countries. The "Climate Resilient and Low Carbon" topic has a high NPMI of 0.48 and eigenvalue of 4.58, indicating strong coherence and significance in Myanmar's land transport discourse environmental components (Table 4 and Fig. 3). This may reflect its vulnerability to cyclones, floods and droughts throughout the country. Low-carbon energy transport and industrial systems are also central to the country's transportation planning and policy, as evidenced by strategy 5.2 in Myanmar's national policy.

The emphasis on "industrial, transport, climate, systems, energy" (Fig. 3), highlights a combined approach to addressing climate change in the transport sector. Myanmar appears to be prioritizing the development of climate-resilient and low-carbon transport systems as part of its broader sustainable growth and economic diversification, in line with strategy 3.6.5 (Table 1, (iii)) which ensures environmental safeguards against negative impacts of infrastructure development (including transport). The inclusion of "sectors" and "industrial systems" in Table 4 also showcases a holistic view, recognizing the interconnectedness of transport (sections 3.6.6 to 3.6.11) with other industries and infrastructure.

4.2.4. Thailand

Thailand's documents discuss advanced technologies, which differs significantly from other countries. The topic "Facilitate Infrastructure" with an NPMI of 0.40 and eigenvalue of 3.13 (Table 5) suggests that infrastructure facilitation is a well-defined and consistently discussed topic, which is important in Thailand's overall transportation strategy. Infrastructure development for "enhancement" of "connectivity" and "competitiveness" is a key driver in policy and development discussions.

The diverse keywords, "networks", "science", "technology", "digital", and "logistics" in the topic reflect a wholistic view of infrastructure development, underlining intermodal hub development. Terms like "competitiveness" and "enhancement" suggest that infrastructure facilitation is closely tied to economic development goals. The inclusion of "tourism infrastructures" and "world" hints at efforts to connect land transportation with other sectors leading to a multi-modal integration. Additionally, keywords such as "digital" and "technology" (Fig. 4), as illustrated through its intelligent transport systems, indicate a strong focus on modernizing transportation infrastructure and this seems to be reflected in the rise in EVs as discussed by Wattana and Wattana (2022).

4.2.5. Vietnam

Vietnam focuses on urban public transport as a tool for greener urban development. The high NPMI of 0.55 and eigenvalue of 4.83 for the "Urban Development" topic (Table 6) indicate a highly coherent and significant theme in urban planning discourse. The NPMI suggests strong associations between transport and sustainable urban development. The high eigenvalue underscores its central importance in shaping policies and strategies. This means that sustainable, clean, and energy-efficient urban development is a key priority in the corpus, and impacting on interconnected sectors including transportation, energy, and public infrastructure.

The NPMI of 0.30 and eigenvalue of 2.33 for the "Climate Change" topic (Table 6) indicate that climate change is moderately coherent and significant theme in transportation discourse. This means that climate change is viewed through various lenses, including environmental protection, natural resource management, and sustainable transportation. This is illustrated in the word cloud (Fig. 5) through key terms like "green transport", "clean" and "sustainable", and as evidenced by the rise of EVs and buses in Vietnam.

Lastly, the NPMI of 0.28 and eigenvalue of 1.70 for the "Promote Market" (Table 6) topic indicate a moderately coherent but less dominant theme in transport sector discourse. The NPMI suggests a coordinated approach to promote market in transportation by a "complete policy", with related sectors such as "energy". As per Article IV subsection 1(3), the role of Ministry of Transport's tasks is to implement development projects steering the transport market towards a green and sustainable growth with more vehicles using clean, economical and efficient energy. The lower eigenvalue for the "promote market" topic

Table 2
Text mining metrics for Cambodia (Source: Wordstat, 2024)

Topic	Keywords	NPMI	Eigenvalue	Policy Document (s)
Operating expenditures Loss of fuel	Electrification, rail, operating, loss, fuel, expenditures, **transportation**, vehicle, public, significant, fuel loss, operating expenditures	0.58	3.66	1
Electric Vehicles	Electric vehicles, buses, urban, **transportation**, reduced, **electric transport**	0.31	2.17	1
Financing Plan	Financing plan, international, public, finance, **transportation,** funding, financing plan	0.28	1.81	1

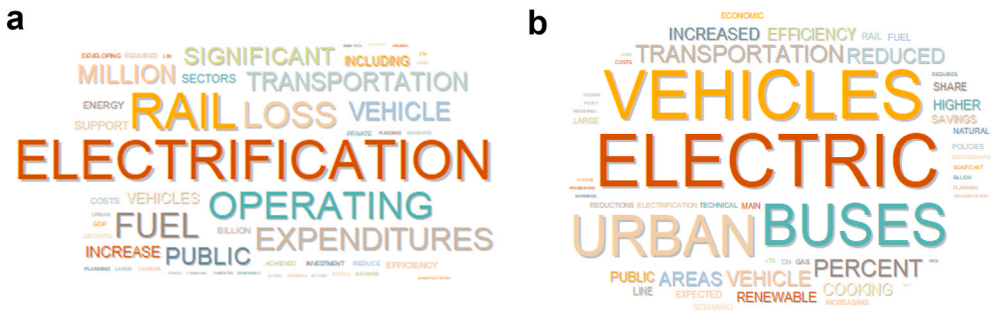


Fig. 1. (a) Word cloud for Cambodia (WordStat, 2024). (b) Word cloud for Cambodia (WordStat, 2024).

Table 3
Text mining metrics for Laos (Source: Wordstat, 2024).

Topic	Keywords	NPMI	Eigenvalue	Policy Document (s)
Public works Transport	**Transport**, works, public, ministry, commerce, vehicles, industry, **transportation** Ministry of Public works, public works, and **transport sector**, forestry, agriculture, energy and mines	0.29	2.47	1

Fig. 2. Word cloud for Laos (Source: Wordstat, 2024).

reflects its broad relevance across multiple sectors and ministries beyond transport (energy, finance, science and technology, construction inter alia) rather than indicating lesser importance in policy discussions.

4.3. Text mining results: regional comparative analysis

The regional policy documents of the Mekong region (Table 1 (i) to (v)) are consolidated into a single corpus in WordStat. The NPMI of 0.42 (Table 7) suggests a moderate to strong association between the words related to public transportation and EVs in the corpus. This suggests that public transportation and EVs are often discussed together or in similar contexts that discusses "fuel" efficiency and "energy" consumptions in transport. This association indicates that Mekong countries' policy-makers consider these concepts as interconnected elements of sustainable transportation strategies. The eigenvalue of 2.31 suggests that the public transportation and EV topic is a substantial and well-defined theme within the analyzed documents. Similarly, the topic "carbon capture and storage (CCS)" shows moderate coherence (NPMI: 0.33) and significance (eigenvalue: 2.88) in Table 7 and in the corpus. This suggests that carbon capture and storage is a notable theme, interconnected with various aspects of sustainable transportation and infrastructure. The diverse keywords indicate a multidisciplinary approach, linking CCS to electric transportation, grid systems, and climate change mitigation.

The prominent words such as "transportation," "costs," "rail," "fuel," "vehicles," and "electric" in word cloud Fig. 6 (a) indicate a focus on traditional aspects of transportation infrastructure, while Fig. 6 (b) indicates the rise of EVs in the region through words like "electric", "transportation", "carbon" inter alia.

Additionally, the main transportation-related sections from the national six policies in Table 1, Appendix A and Flow Diagram 1, respectively, have been systematically reviewed and categorized (Table 8). Economic disparities influence transport strategies across the region. Countries with low GDP per capita tend to have fewer quantifiable targets. The Mekong countries prioritize road investment and efficient public transit (buses), EVs and fuel-efficient vehicles, while rail is not always available as an option due to its costs. Thailand leads in ITS implementation, thanks to its economic and technological advantages. Net-zero goals and decarbonization strategies are present in most countries, with Myanmar and Laos, two low-GDP countries, lagging. Legal frameworks exist in some relatively advanced nations. Only Myanmar incorporates regional commitments into national policy (during the liberalization period).

Fig. 3. Word cloud for Myanmar (Source: Wordstat, 2024).

Fig. 4. Word cloud for Thailand (Source: Wordstat, 2024).

Table 4
Text mining metrics for Myanmar (Source: Wordstat, 2024).

Topic	Keywords	NPMI	Eigenvalue	Policy Document(s)
Climate Resilient Low Carbon	Low, resilient, carbon, industrial, transport, climate-systems, energy, sectors, **transport**, and industrial systems promoted, climate resilience and low carbon, low carbon	0.48	4.58	1

Table 5
Text mining metrics for Thailand (Source: Wordstat, 2024).

Topic	Keywords	NPMI	Eigenvalue	Policy Document(s)
Facilitate Infrastructure	Networks, science, **transport,** technological, ecosystem, tourism infrastructures, world, **transportation**, digital, logistics, technology, connectivity, protective, competitiveness, enhancement, infrastructure development	0.40	3.13	2

Table 6
Text mining metrics for Vietnam (Source: Wordstat, 2024).

Topic	Keywords	NPMI	Eigenvalue	Policy Document(s)
Urban Development	Urban, percentage, cities, public, **transport,** clean, sustainable, development standards, energy, development, regulations, growth, develop green, system	0.55	4.83	1
Climate Change	Change, climate, protection, environmental, natural, management, efficiency, **transport,** sustainable	0.30	2.33	1
Promote Market	Promote market, complete policies, direction, **transport**, development, research, management, efficiency, energy, reduce, standards, solutions, applications	0.28	1.70	1

Fig. 5. Word cloud for Vietnam (Source: Wordstat, 2024).

5. Discussion

5.1. Comparative Mekong policy content and critical analysis based on the theory of change model

Cambodia, Laos, Myanmar, Thailand, and Vietnam share the common goals of improving transportation infrastructure, promoting clean energy, and enhancing public transportation systems, aligning with global sustainability and climate goals. Yet, these Mekong countries employ strategies with varying priorities, reflecting their needs for economic growth as well as technical and institutional capabilities (Appendix A and Flow Diagram 1). Vietnam and Thailand have adopted comprehensive long-term approaches with specific targets, reflecting their advancing economic development status. Beyond policy document (v) in Table 1, Vietnam has also developed a green energy strategy in 2022 with primary objective of mitigating carbon and methane emissions in the transportation industry in line with its COP26 commitments (Thanh, 2022). Consequently, Vietnam ambitiously aims for 100 % of road transport, including public vehicles, to be electric or powered by green energy by 2050 (Fox, 2022; Thanh, 2022). Thailand, similarly, targets a 30–40 % reduction in transport sector emissions by 2030 and carbon neutrality by 2050, supported by detailed policy frameworks and incentives (Orschulok, 2023). Thailand also focuses on intelligent transport systems (ITS), leveraging advanced technologies such as real-time traffic monitoring and smart mobility solutions, and intermodal connection enhancement, with the aim of improving traffic management, safety and efficiency and supporting its goal to become a regional transport hub (Choosakun et al., 2021).

On the other hand, Laos, Myanmar, and Cambodia focus on immediate green growth initiatives. Cambodia focuses on intermodal freight hub development as this is closely linked to enhancing connectivity between its major ports, border areas, and economic zones, exemplified by projects like the Sihanoukville and Phnom Penh Logistics Complexes (Kingdom of Cambodia, 2023; Sopheavatey, 2024). This will in turn strengthen its position as a regional logistics and trade gateway within the Greater Mekong sub region (Whitehead, 2024).Vietnam, on its part, focuses on urban, rail and public transport infrastructure development (bus and road enhancement) to address severe urban congestion and to improve interoperability between rail and other public transport modes, particularly in major cities like Hanoi and Ho Chi Minh City (B&Company, 2025; Hien, 2025). These efforts aim to create an integrated, more sustainable, efficient, accessible, and environmentally friendly urban mobility networks. Laos is investing in bus operational improvements, particularly through the development of Bus Rapid Transit (BRT) systems, as a cost-effective and environmentally friendly solution that can reach a wide segment of Vientiane's population. This approach is intended to reduce greenhouse gas emissions, alleviate traffic congestion, and provide accessible, green mobility options for Vientiane's growing urban areas (ADB, 2021).

Lastly, Myanmar's focus on rural connectivity is to provide all-season road access to about 80 % of villages by 2030, improving access to services and economic opportunities for rural populations, in line with its National Strategy for Rural Roads and Access (2017). Rail decarbonization efforts are also key, though Myanmar's rail infrastructure is also strategically used by the military for logistics, complicating development projects due to their dual-use nature and raising concerns about the military's reliance on rail networks for troop and equipment movement (Justice for Myanmar, 2023). Electric vehicles (EVs) promotion is universal and public transportation enhancement is a common goal, with Cambodia and Thailand establishing modal share objectives. The five countries under study also converge towards fuel efficient/low carbon transportation with fuel efficient vehicles being prioritized. All nations anticipate reduced congestion, improved air quality, and enhanced energy efficiency, alongside economic benefits. While environmental impact reduction is a shared aim, Thailand sets the most

Table 7
Text mining metrics for the 5 Mekong countries (Source: Wordstat, 2024).

Topic	Keywords	NPMI	Eigenvalue	Policy Documents
Public transportation	Transportation; costs; rail; electric expenditures, public vehicles, operating, vehicle, storage, fuel, reduced, logistics, gas	0.42	2.31	6
Electric vehicles	Public transportation, loss of fuel, transportation sector, energy and transportation, electric vehicles			
Carbon capture and storage	Carbon capture and storage, **public transportation,** low carbon, grid, concrete, warming, flexibility, electric, financing, rail, warming	0.33	2.88	6

Table 8
Patterns in land transportation based on country-specific policies.

Patterns in land transport by country-level	GDP per Capita Low ⇔ High				
	Myanmar	Cambodia	Laos	Vietnam	Thailand
1. Targets/Goals					
• Clear net-zero targets	†	✓	†	✓	✓
• Energy efficiency targets	✓	✓	†	✓	✓
2. Strategies					
• Decarbonization strategies (use of clean energy sources including solar and hydro)	†	✓	✓	✓	✓
• Green financing and legal framework	†	×	✓	✓	✓
3. Transport Policies					
• Rail development	×	✓	×	✓	✓
• Public investment in infrastructure: roads	✓	✓	✓	✓	✓
• Public investment in infrastructure: public transits (bus)	✓	✓	✓	✓	✓
• Electric vehicles (EVs)	✓	✓	✓	✓	✓
• Implementation of Intelligent Transport Systems (ITS)	×	×	×	×	✓
• Fuel efficiency/low carbon transport (subsidizing fuel-efficient vehicles)	✓	✓	✓	✓	✓
4. Regional Integration and Commitment					
• Regional commitment (Greater Mekong Subregion, ASEAN Economic Community)	✓	×	×	×	×

✓: Applicable, × : Not Applicable, †: No clear/quantifiable target.

ambitious target of 50 % emissions reduction by 2050 compared to 2020 levels (Appendix A). Cambodia and Thailand explicitly target carbon neutrality by 2050, while the others imply contributions to net-zero goals. The countries' approaches reflect their unique socio-economic contexts and development stages, demonstrating a regional, varying, commitment to sustainable transport that balances economic growth with environmental protection.

5.2. Socio-economic and financial factors

The Mekong countries' transportation approaches reflect their economic status, classified as low (Cambodia, Myanmar), medium (Laos, Vietnam), and high (Thailand) based on pre-COVID GDP per capita (World Bank, 2024b). This classification explains their infrastructure priorities and investment capabilities.

The Mekong region's focus on EVs in decarbonization is closely linked to significant presence of Chinese EV manufacturers. Chinese automakers are strategically relocating their EVs production to Thailand to circumvent United States tax barriers, reduce costs, and gain more market access to the SEA markets (Ayuttacorn, 2023). Moreover, Chinese investors form networks with local corporations through business clusters in Thailand's Eastern Economic Corridor, expanding their regional market presence. Besides Thailand, Chinese EV producers are expanding their production capacities in Indonesia, Malaysia, and Vietnam, rooting deep down their economies (Yuan et al., 2024). From a sales perspective, Chinese automaker brands accounted for 14 % of Thailand's light-vehicle sales in the first of 2024, and among the EV sales, Chinese firms are estimated to account for over 80 % of the Thai market (Yuan et al., 2024). Chinese EV makers are growing their share in other SEA countries, as consumers of these countries often prioritize affordability.

Public investment in roads and buses is common across all income levels (Table 8) due to lower initial costs and environmental benefits (Li et al., 2024). Lower-income countries like Myanmar focus on immediate needs, such as bus transportation over rail development, which requires substantial upfront investment (Table 8). High-income, newly industrialized country like Thailand emphasizes advanced infrastructure, including multi-modal integration (Archarya and Morichi, 2007) and ITS. Vietnam's rapid urbanization drives its urban development focus, ranking second in urban population percentage (36.6 %) after Thailand in 2019 (Appendix A).

China's influence on mega infrastructure transport projects in Southeast Asia, particularly through the Belt and Road Initiative (BRI), has reinforced fossil fuel dependency in Laos, Vietnam, Cambodia, Thailand, and Myanmar. Large-scale transport projects such as railways bridges, and highways have often prioritized economic connectivity over environmental sustainability, increasing fossil fuel use and emissions (Lechner et al., 2021). These projects can hinder national efforts to decarbonize, especially given the fact that Southeast Asia has one of the fastest-growing rates of greenhouse gas emissions globally, primarily driven by increasing fossil fuel combustion (Aleluia et al., 2022). Moreover, the financial and political leverage China holds often limits the Mekong local governments' ability to negotiate greener alternatives (Yu, 2021).

Laos' involvement in the China-Laos railway project, despite its medium economic status, raises concerns about high debt dependency and a debt trap (Chen, 2020). Empirically, the China-Laos railway project, which is almost half of Lao's GDP at USD 6 billion, is financed mostly by China Exim Bank (Chen, 2020), with only 12 % of the project's financing by Lao. In terms of net ODA and official aid received, Myanmar, Cambodia, and Vietnam top the list in 2019. Cambodia also has the highest net ODA receipt as a percentage of gross capital formation at 14.7 % in 2019 (Appendix A). Cambodia's heavy reliance on ODA for infrastructure development indicates limited financial and institutional capacity and a proliferation of donor-driven projects prioritizing reporting to donors over the government while competing for limited qualified human capital (Eckardt and Hayati, 2023; Godfrey et al., 2002; ADB, 2024). Lastly, Myanmar uniquely demonstrates a clear regional commitment in its policy framework, reflecting its political situation at the time the document was published.

From a financial perspective, topics of "financing plan" for Cambodia and "promote market" for Vietnam in their transport discourses suggest the importance of ensuring funding sources. However, both topics appear less central to policy discussions compared to other themes. Cambodia's focus on financing plans suggests a recognition of the need for funding strategies in line with the country's heavy dependence on ODA. Vietnam's emphasis on market promotion in transport development reflects a shift towards market-oriented solutions and efficiency. As the country reduces its reliance on ODA (Appendix A), it faces the challenge of devising innovative financial schemes to sustain and expand its transportation investments. This suggests potential opportunities for more comprehensive financial planning and market-driven approaches in both nations' transport strategies.

In terms of land transport financing for mega infrastructure projects, there is an increased influence of Chinese and international development agencies in the Mekong region. Over the past two decades, China has emerged as the leading provider of international development finance to low- and middle-income countries, surpassing traditional institutions like the World Bank and the International Monetary Fund (Horn et al., 2021). With annual lending commitments averaging USD 85 billion, China outspends the U.S. and EU by significant margins in development finance (Malik et al., 2021). This approach fills a gap left by Western aid agencies and multilateral development banks. These institutions have become increasingly cautious about financing projects

Fig. 6 (a). Word clouds for the corpus involving all 5 Mekong countries (Source: WordStat, 2024).

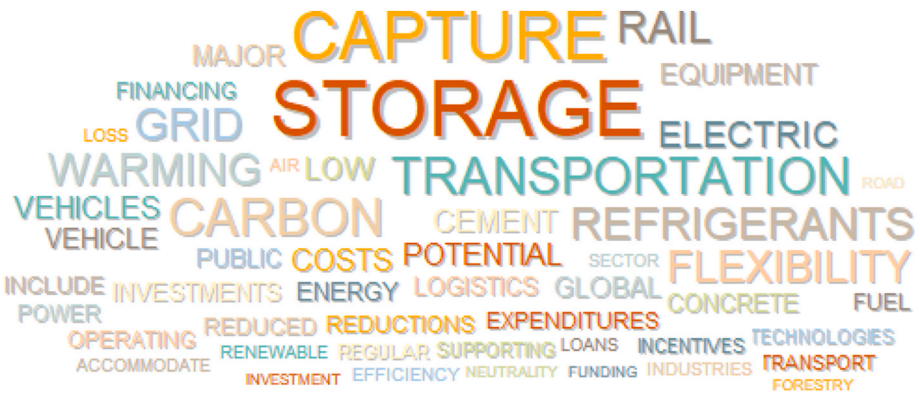


Fig. 6 (b). Word clouds for the corpus involving all 5 Mekong countries (Source: WordStat, 2024).

with potential environmental risks. Instead, China positions itself as the developing world's largest official creditor and preferred financier for major "big-ticket infrastructure projects" (Baehr et al., 2023; Malik et al., 2021). China's focus is primarily on funding large-scale infrastructure projects, including transportation networks and energy facilities (Bluhm et al., 2018). While such projects may be realized faster, aiding economic development, environmental costs often accompany them (Baehr et al., 2023; Guillaume et al., 2018; Zeng et al., 2018; Teo et al., 2019).

5.3. Environmental impact

The common thread across the six policy documents analyzed (Tables 7 and 8), is the prevalence of EVs as an effective measure to decarbonize the land transport sector. As discussed in Section 2, the rise of EVs is in all five Mekong countries. They also prioritize fuel-efficient vehicles and low-carbon transport (Hak et al., 2017; Herrador, 2024) and public investment in infrastructure, particularly roads and bus transit systems (Htike, 2017; Liu et al., 2023; Miatto et al., 2021) to enhance sustainable mobility.

Besides such commonalities, the countries differ in their level of integration and prioritization of environmental concerns in transport policies. Myanmar's strong commitment to climate resilience and low-carbon strategies in its transport sector, as evidenced in the text mining analysis (Table 4), contrasts with the absence of clear net-zero targets for transportation (Table 8). This discrepancy likely stems from Myanmar's high dependence on ODA due to its economic challenges Appendix A. The emphasis on environmentally and socially justifiable projects appears to be driven by international pressure rather than emerging organically from domestic policy priorities. Moreover, as reiterated, Myanmar's policy was published before the military coup. Thus, the country's green transportation reforms and rail and road decarbonization projects had been largely stalled since the military coup, as national priorities have shifted, and many climate and environmental initiatives were either halted or reversed. These underline the intricate balance developing countries such as Myanmar must strike between external aid, national development, political stability and climate action. Pursuing net-zero and decarbonization goals in land

transportation becomes challenging for developing nations when faced with competing politically sensitive in-country priorities such as health, education, and water management (UNICEF, 2019).

Laos's approach to infrastructure development and energy policy reveals a complex interplay of centralized planning and sectoral fragmentation. While the government-led strategy aims to boost socio-economic progress (Table 4), the lack of energy efficiency targets and clear net-zero goals (Table 8) exposes a critical disconnect between infrastructure development and sustainability objectives. This misalignment is particularly evident in the absence of synergies between the transport and energy sectors, two inherently interconnected sectors, in line Dixon et al., (2023). The absence of cohesive policies linking transport and energy sectors (including Laos), underlines a policy gap and a missed opportunity to leverage cross-sectoral synergies for more effective transport decarbonization efforts (Azhgaliyeva et al., 2024).

6. Conclusions and policy implications

The Mekong countries face diverse challenges in realizing green transportation strategies. First, socioeconomic factors, as identified through content analysis, inform the direction of green transportation strategies. For instance, all five countries converge toward fuel-efficient/low-carbon transportation, with fuel-efficient vehicles being prioritized in the region. There is also public investment in public buses due to its environmental benefits and low initial costs. Additionally, all five countries also converge on EVs adoption, signaling a common thread in decarbonizing the region's transport sector. Significant presence of low-cost EV by Chinese makers is not ignorable in interpreting this commonality. The rise of EVs in the Mekong region has also underlined an important issue in transport electrification, that is, the lack of coordination between the transport and energy sectors, as evidenced in Laos. The lack of coordination between transport and energy ministries results in "silo" planning as stated by Dixon et al., (2023), resulting in unbalanced GHG emissions. As evidenced in Thailand, while EVs reduce GHG emissions in the transport sector, they also increase emissions from power generation (Winyuchakrit et al., 2017). Laos also faces sectoral fragmentation as discussed in Section 5.2. In fact, energy modeling literature of the Global South lacks studies exploring emissions reduction potential across different transport sub-sectors (Emodi et al., 2022).

This research also underlines (Diagram 2) how financial and institutional capacity are two major sources of diversion from the common policy directions. Cambodia and Myanmar's high ODA reliance leads to donor-dependent transport projects while Laos prioritizes high-cost rail development due to Chinese funding as well as investment in public transport (bus) due to its relative low cost. In Myanmar, the military coup has stagnated climate actions despite its ambition during the liberalized period. Finally, Thailand and Vietnam, with high financial and institutional capacities set clear objectives and make steady progress towards low carbon transportation goals, with Thailand emphasizing Intelligent Transport Systems (ITS) and Vietnam prioritizing urban and rail infrastructure development.

The challenges facing sustainable land transportation in the Mekong region present policy implications. There is inter-sectoral coordination to attain overall net-zero goals. In the case of EV adoption, the limited technological capabilities and EV adoption barriers necessitate a comprehensive policy approach that links the transport and energy sectors. To address these challenges, policymakers should consider implementing phased transition plans, leveraging public-private partnerships (PPPs), particularly in countries with limited or underdeveloped PPP frameworks, such as Cambodia, Laos, and Myanmar, compared to more industrialized nations like Thailand and Vietnam, for infrastructure development. This will ensure net-zero targets are applicable in all target Mekong countries and will better establish regional multisectoral cooperation frameworks. The focus should be on creating supportive regulatory environments for new technologies, innovative finance, incentivizing green transportation solutions, and investing in capacity-building programs.

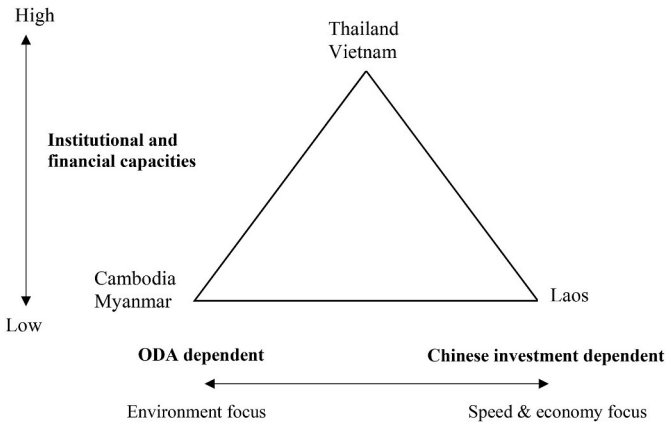


Diagram 2. Policy priorities and divergence in the Mekong region (Source: Authors, 2025).

Another critical factor is the need for proactive efforts to ensure a green financing source. Governments in the Mekong region, especially those with lower economic status, should prudently manage infrastructure loans to avoid falling into debt traps. Transitions to green transportation, such as rails and EVs, often demand reallocation of resources toward infrastructure development and technological upgrades, which could strain already limited budgets in a developing region. However, if policymakers prioritize short-term financial availability and economic development over long-term financial independence and sustainability goals, it may result in unwanted environmental and political consequences. The Mekong countries should also implement stringent environmental impact assessments and require sustainable development practices as preconditions for project approval and funding acceptance.

Finally, several limitations should be acknowledged for this study. Firstly, this pilot research is constrained by its focus on only six national policy documents, which do not capture the full spectrum of transportation and infrastructure policies. This limited scope could potentially omit variations and updates present in other policy documents or sector-specific strategies. Additionally, this study's reliance on a core set of national strategy documents, while methodologically necessary for a structured comparison, oversimplifies the cross-country policy landscape. This focus overlooks critical nuances and synergies found in sectoral plans, legislation, implementation programs and institutional frameworks. Secondly, the reliance on text mining software may not fully capture the contextual nuances or implicit policy intentions. The cross-sectional nature of the data also provides a snapshot view, potentially missing temporal policy evolutions. Thirdly, there is the use of the English translation for some of the policy documents originally written in its native language. This translation process may lead to the loss or misinterpretation of cultural contexts, or specific terminologies. Lastly, the cross-country comparison may not fully account for the diverse socio-economic contexts and development stages of each Mekong country, which could influence policy priorities and implementation strategies. Future research is anticipated to overcome these shortcomings, possibly with qualitative research or assessment of a larger volume of policy documents from the region in a native language.

CRediT authorship contribution statement

Hansha Kistamah: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Miwa Matsuo:** Writing – review & editing, Visualization, Validation, Supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2025.103845.

Data availability

Data will be made available on request.

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