

Technical and Economic Gaps in Freight Diesel-to-Natural Gas Transition – A Conceptual Analysis

Lennon de Almeida Freire, Savio Figueira Corrêa and Sérgio Evangelista Silva

Universidade Federal de Ouro Preto (UFOP), MG, Brasil

lennon.freire@aluno.ufop.edu.br

saviofcorrea@ufop.edu.br

sergio.silva@ufop.edu.br

Abstract: Heavy-duty road freight transport plays a central role in contemporary logistical systems but remains heavily dependent on diesel, making it a primary driver of atmospheric emissions, intensive fossil fuel consumption, and exposure to energy cost volatility. Given this scenario, the transition to alternative energy technologies has been widely discussed in academic literature, particularly within the contexts of sustainability, innovation, and organisational competitiveness. Among these alternatives, natural gas-based technologies—such as Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG)—have received significant attention for their potential to serve as transitional solutions in the short and medium term. Despite the growing volume of studies on the subject, existing literature addresses the energy transition in road freight transport in a fragmented way. Technical research focuses on engine performance, energy efficiency, and emissions, while economic studies focus on financial indicators such as Total Cost of Ownership (TCO) and payback periods. Meanwhile, organisational and behavioural approaches analyse institutional factors and technology acceptance. These strands progress largely in isolation, with limited integration between technical and economic issues, which restricts effective decision-making support within organisational and corporate environments. In this context, this article aims to critically examine the fragmentation of scientific literature regarding the transition from diesel to alternative energy technologies in heavy-duty road freight transport, and to propose a conceptual framework integrating technical and economic feasibility. The study adopts a theoretical-analytical approach based on critical synthesis of the literature, thereby addressing a gap in the integration of techno-economic dimensions in existing research. The article organises the technical, economic, and decisional dimensions involved in the energy transition, repositioning the debate beyond isolated environmental assessments. In doing so, it establishes a clear conceptual foundation for the development of integrated performance evaluation models and for future empirical investigations aimed at supporting strategic decision-making in the road freight transport sector. This approach contributes to bridging the gap between technical performance and economic decision-making in energy transition studies. The proposed framework is particularly relevant for fleet managers, logistics operators, and policymakers operating in contexts characterised by infrastructure constraints, regulatory uncertainty, and cost sensitivity.

Keywords: Energy Transition, Green Innovation, Economic Feasibility, Performance Assessment, Freight Transport

1. Introduction

Road freight transport occupies a pivotal position within contemporary logistics systems, particularly in countries characterised by large territories and a pronounced reliance on this mode for the movement of goods. Despite its economic and operational significance, the sector remains deeply anchored to diesel as its primary energy source. This dependency casts a long environmental shadow, placing road freight among the leading contributors to atmospheric emissions, a reality acknowledged across the literature as a defining feature of freight transport systems in diverse national contexts (Cantillo et al., 2022; Zhao et al., 2021).

However, when considered collectively, a structural limitation emerges. Within this landscape, the transition towards alternative energy technologies has steadily emerged as a strategic focal point in both academic discourse and managerial practice, where sustainability, innovation, and logistical performance increasingly intersect. The literature on green logistics and sustainable supply chain management suggests that the adoption of environmentally oriented practices can yield tangible gains in organisational performance, operational efficiency, and competitive positioning—particularly when such practices are woven into the broader fabric of business strategy (Martinsen & Hüge-Brodin, 2014; Wang & Hu, 2021).

Among the alternatives to diesel explored in the literature, natural gas-based technologies—most notably compressed natural gas (CNG) and liquefied natural gas (LNG)—have attracted considerable attention for their potential to strike a delicate balance between technical performance, economic viability, and environmental impact mitigation. Experimental studies indicate that heavy-duty engines operating on natural gas, including dual-fuel configurations, can achieve levels of torque, power, and energy efficiency that closely mirror those of conventional diesel engines across a range of operating conditions. Such findings lend weight to the argument for their technical feasibility in freight transport applications (Karczewski & Wiecek, 2021; Karczewski & Szamrej, 2023).

From an economic standpoint, a growing body of research has turned to total cost of ownership (TCO) and life-cycle costing approaches as lenses through which alternative energy technologies may be comparatively assessed. Empirical evidence suggests that, under certain operational conditions, natural gas-powered vehicles may offer economic advantages over their diesel counterparts, driven primarily by lower fuel costs and a more predictable maintenance profile (Zhao et al., 2021; Zhang et al., 2024). These insights reinforce the view that natural gas may serve as a transitional technology in the short to medium term, particularly in contexts where infrastructure availability and route characteristics are conducive to its deployment.

Despite the accumulation of relevant technical and economic evidence, the body of literature addressing energy transition in heavy-duty road freight transport remains markedly fragmented. Technical studies tend to concentrate on engine performance, fuel consumption, and emissions, while economic analyses predominantly privilege financial indicators such as TCO and payback periods (Katreddi et al., 2023; Karczewski & Szamrej, 2023). In parallel, behaviour-oriented research explores perceptual factors and institutional barriers, often without establishing explicit connections to vehicle performance metrics or to the tangible economic outcomes of freight operations (Cantillo et al., 2022).

As a result, a significant gap becomes apparent in relation to the critical and integrated assessment of techno-economic feasibility within this transition. In light of this, the present study sets out to critically examine the fragmentation of existing approaches in the literature and to argue for the need for an integrated analytical framework capable of capturing the interplay between technical and economic dimensions in the transition from diesel to alternative energy technologies in heavy-duty road freight transport. By adopting a theoretical-analytical approach based on critical literature synthesis, the study contributes to addressing the lack of integration between technical and economic dimensions, offering a structured conceptual basis to support organizational decision-making, particularly for fleet managers, logistics operators, and policymakers operating in contexts of infrastructure and regulatory uncertainty.

2. Evidence of the Research Gap

Building on the previous discussion, the scientific literature addressing the energy transition in heavy-duty road freight transport has expanded markedly, reflecting the mounting regulatory, environmental, and economic pressures placed upon a sector still firmly reliant on diesel as its primary energy source. However, despite the breadth of studies available, existing contributions appear dispersed and unevenly articulated, with notable advances achieved within specific dimensions, yet only limited integration across technical, economic, and decision-making aspects. It is precisely this analytical fragmentation that lies at the heart of the research gap examined in this article.

2.1 Fragmentation of Approaches in the Literature on Energy Transition

Building on this perspective, a cross-cutting examination of the existing body of research reveals that the transition from diesel to alternative energy technologies in heavy-duty transport is approached through multiple, largely isolated perspectives. As a result, the capacity to support complex technological decision-making within the operational context of heavy-duty road freight transport remains constrained (Karczewski & Wieczorek, 2021; Katreddi et al., 2023).

2.2 Predominance of Isolated Technical Analyses

A substantial portion of the literature is devoted to the technical evaluation of alternatives to diesel, with a primary focus on engine performance, energy consumption, and atmospheric emissions. Assessments conducted under real or representative driving cycles further reinforce the technical feasibility of LNG and CNG for medium- and long-distance applications (Zhao et al., 2021). However, these studies often remain anchored in specific technical or environmental metrics (Zhao et al., 2021; Katreddi et al., 2023).

2.3 A Narrow and Decontextualised Economic Focus

In parallel with technical analyses, a considerable body of research approaches the energy transition through an economic lens, employing indicators such as total cost of ownership (TCO), life-cycle cost, and payback period (Katreddi et al., 2023; Cantillo et al., 2022). Recurring findings suggest that natural gas-powered vehicles may offer economic advantages over diesel, particularly due to lower fuel costs and, in some cases, reduced maintenance expenses (Zhao et al., 2021; Zhang et al., 2024). However, these analyses often neglect operational

variability (Katreddi et al., 2023; Karczewski & Szamrej, 2023). As a result, economic analyses often fail to engage meaningfully with the technical outcomes observed under real operating conditions, which, in turn, constrains their effectiveness in informing sound technological transition decisions (Karczewski & Szamrej, 2023).

2.4 Environmental Assessments Disconnected From Decision-Making Logic

Another important strand of the literature focuses on the environmental evaluation of alternatives to diesel, with particular emphasis on studies grounded in Life Cycle Assessment (LCA) and Well-to-Wheel (WTW) approaches. These works provide relevant evidence regarding the reduction of greenhouse gas emissions and local pollutants associated with the use of natural gas in heavy-duty vehicles. However, more recent studies, such as that of Karczewski & Szamrej (2023), indicate that the environmental benefits of natural gas may involve meaningful trade-offs, including increased emissions of methane and secondary aerosols under certain operational conditions. This challenges simplified environmental assessments based solely on CO₂ or aggregated Global Warming Potential (GWP). However, these assessments are rarely integrated with economic analyses or with the decision-making logic of firms.

2.5 Behavioural and Organisational Studies Without Techno-Economic Integration

The literature also encompasses studies aimed at understanding the behavioural and organisational factors that shape the adoption of sustainable technologies in transport. These works highlight institutional barriers, risk perception, infrastructure availability, and stakeholder expectations as central elements in the decision-making process (Cantillo et al., 2022). These approaches often lack integration with technical and economic evidence (Martinsen & Hüge-Brodin, 2014; Khan et al., 2019). Empirical evidence suggests, however, that organisational acceptance of alternative technologies is strongly conditioned by perceived profitability, operational reliability, and actual costs—factors that call for a rigorous integration of technical and economic analyses (Pfoser, 2022).

2.6 Limitations of Existing Frameworks and Multicriteria Approaches

In an effort to bring together multiple dimensions of sustainability, some studies propose conceptual frameworks and multicriteria methods for the evaluation of energy technologies. Approaches grounded in AHP, DEMATEL, EDAS, and structures derived from the triple bottom line seek to consider technical, economic, and environmental criteria simultaneously (Alonso-Villar et al., 2022). However, when applied to the specific context of heavy-duty road freight transport, such frameworks reveal notable limitations. These frameworks often lack applicability to real operational contexts. (Alonso-Villar et al., 2022). As a result, these approaches often provide only limited support for decision-making in real-world energy transition contexts.

2.7 Critical Synthesis of the Research Gap

An integrated reading of the literature reveals that, although there have been meaningful advances in the technical, economic, environmental, and organisational assessment of energy transition in heavy-duty road freight transport, these strands of progress remain largely disconnected from one another. The principal limitation of existing frameworks lies in their inherently generic character, which often overlooks critical sector-specific features, such as the high sensitivity to torque and the dependence on route-specific infrastructure. The absence of an analytical framework capable of critically and pragmatically integrating techno-economic feasibility under such real-world conditions constrains both the advancement of scientific knowledge and the effective support of organisational decision-making (Khan et al., 2019; Alonso-Villar et al., 2022). This gap underscores the need for a conceptual effort aimed at articulating these dimensions, thereby establishing the foundations for the development of evaluation models specifically tailored to the performance of energy transition in heavy-duty freight transport.

3. Conceptual Framing of the Research

The critical analysis of the literature presented in the previous section clearly highlights the fragmentation of existing approaches and makes it clear that the energy transition in heavy-duty road freight transport cannot be adequately understood through isolated approaches. Within this context, it becomes necessary to establish a conceptual framing capable of organising, in an integrated manner, the core dimensions involved in assessing the feasibility of replacing diesel with alternative energy technologies. This framing rests on the understanding that the energy transition constitutes a matter of technological and organisational performance, rather than merely an issue of environmental compliance.

3.1 Energy Transition as a Problem of Organisational Performance

Studies in the field of green logistics and sustainable innovation suggest that the adoption of environmentally oriented technologies should be examined through the lens of organisational performance, considering their effects on operational efficiency, competitiveness, and value creation (Martinsen & Huge-Brodin, 2014; Wang & Hu, 2021). In this sense, and in response to the fragmentation identified, the energy transition in heavy-duty road freight transport entails long-term strategic decisions, characterised by substantial investments, a strong dependence on physical assets, and direct impacts on the cost structure of operations.

The literature further indicates that technologies such as CNG and LNG may be understood as incremental transition solutions, whose adoption depends less on their isolated environmental potential and more on their ability to enhance—or at the very least sustain—the operational and economic performance of logistics systems (Pfoser, 2022).

3.2 The Dimension of Technical Feasibility in Heavy-Duty Road Freight Transport

Technical feasibility stands as one of the foundational pillars of this framework, defined by the capacity of an alternative technology to withstand and sustain the demanding operational requirements of heavy-duty freight transport. This dimension extends beyond isolated thermodynamic efficiency, encompassing critical parameters such as torque delivery at low engine speeds, power stability on inclines, and mechanical robustness in the face of load variability (Karczewski & Wieczorek, 2021; Karczewski & Szamrej, 2023).

Beyond these force-related parameters, operational range emerges as a decisive factor, particularly in the case of LNG, whose performance under real driving cycles demonstrates compatibility with medium- and long-distance routes (Zhao et al., 2021; Balazadeh et al., 2024).

In this light, the concept of technical feasibility proposed here brings together the reliability of the powertrain and its geographical and operational adaptability. Within this framing, a technology is only deemed technically viable when it demonstrates the capacity to maintain the required level of performance under real-world conditions of use, while minimising the risks of unavailability or accelerated asset degradation (Karczewski & Szamrej, 2023; Balazadeh et al., 2024).

3.3 The Dimension of Economic Feasibility and Decision Rationality

Economic feasibility constitutes the second pillar of this framework and is often the determining factor in shaping the scale of energy transition within commercial fleets. Yet, the perspective advanced here moves beyond a static view of costs, embracing instead the rationality of decision-making under conditions of uncertainty and operational variability (Katreddi et al., 2023; Cantillo et al., 2022).

From this standpoint, Total Cost of Ownership (TCO) is treated as a dynamic variable, sensitive not only to fluctuations in fuel prices but, more fundamentally, to the technology's actual technical performance in the field. Economic feasibility is validated when reductions in direct operating costs are sufficient to offset the capital premium associated with acquiring natural gas-powered vehicles within a time horizon deemed acceptable by the organisation (Zhao et al., 2021; Zhang et al., 2024).

Economic feasibility also depends on cost predictability and perceived risk. Evidence suggests that cost predictability can be as decisive for managers as the absolute magnitude of the savings achieved (Katreddi et al., 2023). In this sense, economic feasibility is defined here as the capacity of the alternative technology to sustain business profitability, mitigate the risks of obsolescence, and preserve the competitiveness of logistics operations in relation to diesel (Karczewski & Szamrej, 2023; Zhang et al., 2024).

3.4 Interdependence Between Technical and Economic Feasibility

A central feature of the proposed conceptual framework lies in the interdependence between the technical and economic dimensions. Evidence drawn from both technical and economic studies indicates that variations in technical performance exert a direct influence on operational costs, particularly those associated with maintenance, energy consumption, and vehicle reliability (Karczewski & Szamrej, 2023; Zhang et al., 2024). Conversely, economic constraints may limit the adoption of technically viable solutions, especially when high initial investments or infrastructure-related costs exceed the financial capacity and capital availability of transport operators (Issa et al., 2024; Pfoser, 2022). This bidirectional relationship underscores the inadequacy

of assessments that treat technical and economic dimensions in isolation, as the performance of one variable inevitably shapes and conditions the outcomes of the other.

3.5 Decision-Making Context and the Integration of Dimensions

The decision-making context forms the final frame within which technical and economic feasibility is interpreted and acted upon by organisations. This dimension acknowledges that the energy transition does not unfold within a purely technical vacuum; rather, it is shaped by institutional pressures, infrastructure availability, and perceptions of strategic risk (Cantillo et al., 2022; Alonso-Villar et al., 2022).

Within this setting, the context operates as a filter of feasibility: regulatory uncertainties or gaps in refuelling infrastructure may render technically sound and economically attractive projects unviable (Khan et al., 2019). The rationale underpinning this framework therefore suggests that the transition to alternative fuels in heavy-duty transport requires a convergence between the technical capacity for implementation, the financial sustainability of the investment, and the contextual viability of the operation (Martinsen & Huge-Brodin, 2014). Seen through this integrated lens, the fleet manager no longer evaluates isolated components but instead oversees the performance of the transition as a long-term strategic asset.

3.6 Synthesis of the Proposed Conceptual Framework

The synthesis of the conceptual framework presented here advances the view that energy transition in heavy-duty road freight transport should be assessed as a system of integrated performance, rather than as a sequence of isolated decisions. This model departs from the fragmented approaches found in the literature by establishing that the real viability of the transition emerges only from a balanced intersection of three critical dimensions: the technical capacity for implementation, the economic rationality of the investment, and alignment with the decision-making context (Karczewski & Wieczorek, 2021; Katreddi et al., 2023; Pfoser, 2022).

The framework integrates technical, economic, and contextual dimensions into a unified analytical perspective (Karczewski & Szamrej, 2023; Zhang et al., 2024). In this sense, the proposed model operates as an analytical instrument for both managers and researchers, offering a coherent foundation for scenario simulation and for supporting strategic decisions aimed at sustaining the competitive performance of logistics operations (Martinsen & Huge-Brodin, 2014; Alonso-Villar et al., 2022).

3.7 Schematic Representation of the Conceptual Framework

As a synthesis of the theoretical discussion presented, Figure 1 illustrates the structure of the proposed conceptual framework. The visual model highlights the central intersection of the three dimensions—Technical Feasibility, Economic Feasibility, and Decision-Making Context—as the point at which the real performance of the energy transition takes shape.

This integration enables a systemic analysis that moves beyond the fragmentation identified in the literature, offering a coherent basis for scenario simulation and for supporting strategic decision-making in heavy-duty road freight transport.

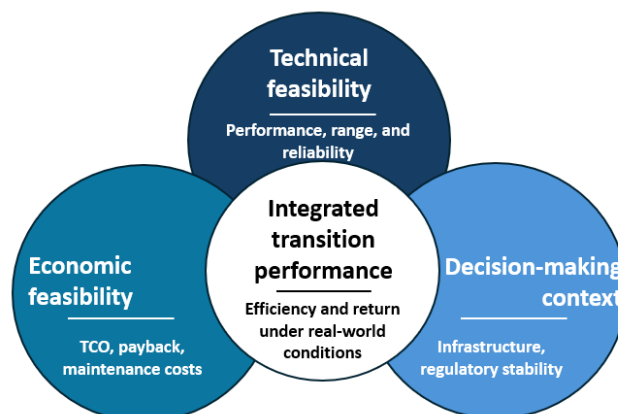


Figure 1: Conceptual framework for evaluating energy transition performance.

Source: Elaborated by the authors (2026).

4. Methodology

4.1 Nature of the Study and Analytical Logic

This study is characterised as conceptual in nature, guided by a theoretical-analytical approach aimed at critically organising the existing literature on energy transition in heavy-duty road freight transport. Unlike empirical investigations, this work does not seek to test hypotheses or validate models through primary data; rather, it endeavours to structure and integrate dispersed contributions within the literature, with the purpose of revealing gaps and proposing a more coherent analytical framing.

This methodological choice is justified by the fragmented nature of the existing literature, which requires critical synthesis rather than empirical validation at this stage. The analytical logic adopted is grounded in the critical synthesis of studies that address, in isolation, the technical, economic, and organisational dimensions of energy transition. From this examination, the study identifies recurring patterns of fragmentation and limitations inherent in purely technical or financial models, weaving these insights into the construction of a conceptual framework oriented towards assessing transition performance through an integrated and systemic perspective.

In this sense, the methodology enables the articulation of dispersed evidence into a structured analytical model, supporting both theoretical advancement and future empirical applications.

4.2 Delimitation of the Analytical Dimensions

The conceptual framework proposed in this study is structured around the articulation of three central dimensions: technical feasibility, economic feasibility, and the decision-making context.

- The technical dimension refers to the capacity of alternative technologies to meet the real demands of logistics operations, including torque, power, reliability, and adaptability to different operating conditions (Karczewski & Szamrej, 2023).
- The economic dimension encompasses the analysis of the costs associated with the adoption and operation of these technologies, considering not only Total Cost of Ownership (TCO), but also cost predictability and exposure to financial risk (Zhang et al., 2024).
- The decision-making context includes factors such as infrastructure availability, regulatory conditions, and the perception of risk among the stakeholders involved (Khan et al., 2019).

These dimensions are treated as interdependent, as technical performance directly shapes operational cash flows, while the conditions of the decision-making context act as the final filter determining the feasibility of technological adoption. This delimitation ensures analytical focus while preserving the systemic nature of the energy transition problem.

4.3 Scope

This study focuses on the conceptual analysis of energy transition in heavy-duty road freight transport, with particular emphasis on the shift from diesel-based technologies to natural gas solutions, including compressed natural gas (CNG) and liquefied natural gas (LNG). These technologies are considered due to their relative maturity and recurrent presence in the literature as transitional alternatives for long-distance operations.

The scope of the proposed framework is deliberately centred on the integration of technical and economic dimensions, as these are identified as the most critical and yet insufficiently articulated aspects in existing studies. Environmental and organisational factors are incorporated as contextual elements that influence the decision-making environment, without constituting the primary analytical focus. This scope reflects the intention to develop a practically applicable framework, particularly relevant for operational and strategic decision-making contexts in freight transport.

5. Research Logic and Proposed Objectives

5.1 Logical Structuring of the Research

The analysis developed demonstrates that the transition to alternative energy technologies in road freight transport is essential for logistical sustainability (Martinsen & Huge-Brodin, 2014; Pfoser, 2022). However, the

logic underpinning this research rests on the recognition that isolated assessments fall short of capturing the complexity of this process, thereby revealing the need for an integrated analytical perspective. As technical performance directly shapes operational costs, and economic conditions, in turn, determine the feasibility of technological adoption (Karczewski & Szamrej, 2023; Zhang et al., 2024), there emerges a clear need for a coherent structure capable of articulating these dimensions within the decision-making context, so as to provide a consistent foundation for organisational decision-making (Cantillo et al., 2022; Khan et al., 2019). This research logic therefore bridges the gap identified in the literature by explicitly linking technical performance and economic feasibility within a unified analytical perspective.

5.2 Scope Delimitation of the Research

This study focuses on heavy-duty road freight transport, a domain in which energy consumption and cost sensitivity are particularly critical. The analysis is directed towards the transition from diesel-based technologies to solutions grounded in natural gas (CNG and LNG), identified in the literature as mature transitional alternatives.

The scope is deliberately centred on the technical and economic dimensions, as these represent the most critical and least integrated aspects within existing approaches. Environmental and organisational factors are incorporated as contextual variables that shape the decision-making environment, allowing the framework to maintain its focus on operational performance without overlooking the institutional and regulatory pressures that characterise the sector (Issa et al., 2024; Khan et al., 2019).

5.3 General Objective of the Article

In light of the gaps identified, this article aims to propose and describe a conceptual framework for the integrated assessment of the technical and economic feasibility of energy transition in heavy-duty road freight transport. This objective reflects the need to support decision-making processes in contexts characterised by operational complexity and uncertainty.

To achieve this objective, the study:

- Examines how the literature addresses technical performance and economic viability in a dissociated manner;
- Identifies the limitations of these approaches when detached from real-world operational contexts;
- Proposes a conceptual structure (figure 1) that brings these dimensions together under a perspective oriented towards organisational performance and strategic decision support.

To support the achievement of this objective and the application of the proposed framework, the following section outlines the methodological perspective and analytical logic underpinning the construction and future operationalisation of this study.

6. Conclusions and implications

6.1 Theoretical and Conceptual Contributions

This article set out to establish a conceptual foundation for a more integrated assessment of the technical and economic feasibility of energy transition. Its primary contribution lies in the critical organisation of this fragmented field and in the proposal of a conceptual framework (Figure 1) that brings together the technical, economic, and decision-making dimensions. By explicitly addressing the lack of integration identified in the literature, the study advances the understanding of energy transition as a problem of integrated performance rather than isolated evaluation. By reframing the transition as a problem of technological-organisational performance, the study offers an analytical perspective more closely aligned with the real operational conditions encountered in heavy-duty freight transport.

6.2 Managerial and Public Policy Implications

From a managerial perspective, the framework contributes to a more structured understanding of the trade-offs involved in the adoption of new technologies. Within the realm of public policy, the findings suggest that incentives for transition should extend beyond vehicle subsidies, placing equal emphasis on regulatory stability and the expansion of refuelling infrastructure, both of which form part of the critical decision-making context

identified. This highlights the need for coordinated policy approaches that consider the interdependence between technological performance, economic viability, and contextual conditions. Policies grounded in partial analyses risk generating distortions, as they overlook the fact that the economic viability of transport operators is intrinsically tied to the availability of this supporting contextual network.

6.3 Research Agenda

The findings of this study point to the need for further advances in investigations capable of empirically operationalising the proposed conceptual framework. Future research should prioritise validation through real-world applications, particularly using fleet-level data and operational case studies. Future research may explore the application of this framework in real-world operational contexts, including analyses based on fleet data, case studies, and quantitative modelling approaches that integrate technical performance and economic feasibility.

In addition, there is scope for the development of analytical models capable of capturing the interdependence between technical, economic, and contextual variables, thereby contributing to a more robust assessment of energy transition performance. Comparative studies across different transition technologies, as well as investigations into the impacts of specific operational conditions, may also deepen the understanding of the phenomenon.

Despite its contributions, this study presents limitations inherent to its conceptual nature. The proposed framework is not empirically validated and does not incorporate quantitative indicators of cost or emissions at this stage. Furthermore, the analysis is primarily centred on natural gas-based technologies, reflecting their maturity in the literature rather than an exhaustive comparison across all possible alternatives. These limitations reinforce the need for future empirical studies aimed at validating and operationalising the proposed framework under real-world conditions.

Ethics Declaration

The authors declare that this research is an original theoretical and conceptual work. The study did not involve experimentation with human or animal subjects. The research was conducted in compliance with ethical standards of academic integrity. The authors further declare that there are no conflicts of interest or financial relationships that could have influenced the work reported in this article.

AI Declaration

The authors declare that artificial intelligence (AI) tools were used as support in the preparation of this manuscript. AI was applied specifically to assist with translation, language refinement, logical structuring of the text, and grammatical correction, aimed at ensuring the clarity and academic rigour required for an international publication. It is emphasised that the theoretical conception, critical literature analysis, and the proposal of the original conceptual framework were performed entirely by the human authors, who take full responsibility for the content and final integrity of this article.

Acknowledgement

Federal University of Ouro Preto Pro-Rector for Research and Innovation (PROPPI) Graduate Program in Production Engineering (PPGEP) at the Federal University of Ouro Preto. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001 (PROAP - PROGRAM).

References

- Alonso-Villar, A. et al. (2022) 'Technical, economic, and environmental feasibility of alternative fuel heavy-duty vehicles in Iceland', *Journal of Cleaner Production*, 369, 133249.
- Balazadeh, N. et al. (2024) 'Predicting transient performance of a heavy-duty gaseous-fuelled engine using combined phenomenological and machine learning models', *International Journal of Engine Research*, pp. 1–18.
- Cantillo, V. et al. (2022) Influencing factors of trucking companies willingness to shift to alternative fuel vehicles. *Transportation Research Part E*, 163, 102753.
- Issa, A. et al. (2024) 'The path from green innovation to supply chain resilience: do structural and dynamic supply chain complexity matter?', *Sustainability*, 16(9), 3762.

- Karczewski, M. and Szamrej, G. (2023) 'Experimental evaluation of the effect of replacing diesel fuel by CNG on the emission of harmful exhaust gas components and emission change', *Energies*, 16(1), 475.
- Karczewski, M. and Wieczorek, M. (2021) Assessment of the impact of applying a non-factory dual-fuel (diesel/natural gas) installation on the traction properties and emissions of selected exhaust components of a road semi-trailer truck unit. *Energies*, 14(23), 8001.
- Katreddi, S. et al. (2023) 'Machine learning models for maintenance cost estimation in delivery trucks using diesel and natural gas fuels', *Frontiers in Mechanical Engineering*, 9, 1201068.
- Khan, S.A.R. et al. (2019) 'Environmental, social and economic indicators of green logistics: documentation of South Asia Association for Regional Cooperation Countries', *Journal of Cleaner Production*, 214, pp. 1011–1023.
- Martinsen, U. and Høge-Brodin, M. (2014) 'Environmental practices as offerings and requirements on the logistics market', *Logistics Research*, 7, pp. 1–22.
- Pfoser, S. (2022) *Decarbonizing freight transport: Acceptance and policy implications*, Wiesbaden: Springer Gabler.
- Wang, S. and Hu, Z.H. (2021) 'Green logistics service supply chain game considering risk preference in fuzzy environments', *Sustainability*, 13(14), 8024.
- Zhang, X. et al. (2024) 'Environment-economic comparison of potential alternative fuel heavy-duty trucks in China', *Transportation Research Part D*, 131, 104206.
- Zhao, Q., Huang, W., Hu, M., Xu, X., & Wu, W. (2021). Characterizing the economic and environmental benefits of lng heavy-duty trucks: A case study in shenzhen, china. *Sustainability*, 13(24), 13522