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Trends and research fronts in fuel consumption forecasting: a bibliometric analysis

Tendências e frentes de pesquisa na previsão do consumo de combustíveis: uma análise bibliométrica

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Abstract: Fuel consumption forecasting is a vital tool for energy planning, economic management, and public policy development. This study conducts a bibliometric analysis to identify trends, research fronts, and collaboration networks in the field of fuel consumption forecasting. A total of 5,025 documents from the Scopus database were analyzed using bibliometric methodologies, including keyword co-occurrence network analysis and S-curve projection. The results indicate an annual scientific production growth rate of 8.64% and suggest that the field may reach saturation by 2030. The findings highlight key research trends, such as the increasing use of artificial intelligence and machine learning to enhance predictive accuracy, as well as the integration of macroeconomic indicators like Gross Domestic Product – GDP and fuel price elasticity. Geographically, China, the United States, and India lead global scientific output, reflecting the strategic importance of fuel consumption forecasting in economic and environmental decision-making. The study also identifies gaps in interdisciplinary research and limited focus on integrating big data and real-time analytics into forecasting models. In conclusion, while fuel consumption forecasting has become a mature research field, further studies should explore emerging technologies and hybrid predictive models to improve accuracy and adaptability. These insights contribute to advancing methodologies and guiding future research agendas in energy management and policy-making.
Keywords: fuel consumption; forecasting; bibliometric analysis; artificial intelligence; energy planning.

Resumo: *A previsão do consumo de combustível é uma ferramenta vital para o planejamento energético, gestão econômica e desenvolvimento de políticas públicas. Este estudo realiza uma análise bibliométrica para identificar tendências, frentes de pesquisa e redes de colaboração no campo da previsão do consumo de combustível. Um total de 5.025 documentos do banco de dados Scopus foram analisados usando metodologias bibliométricas, incluindo análise de rede de coocorrência de palavras-chave e projeção de curva S. Os resultados indicam uma taxa de crescimento anual da produção científica de 8,64% e sugerem que o campo pode atingir a saturação até 2030. As descobertas destacam as principais tendências de pesquisa, como o uso crescente de inteligência artificial e aprendizado de máquina para aumentar a precisão preditiva, bem como a integração de indicadores macroeconômicos como PIB e elasticidade do preço do combustível. Geograficamente, China, Estados Unidos e Índia lideram a produção científica global, refletindo a importância estratégica da previsão do consumo de combustível na tomada de decisões econômicas e ambientais. O estudo também identifica lacunas na pesquisa interdisciplinar e foco limitado na integração de big data e análises em tempo real em modelos de previsão. Concluindo, embora a previsão do consumo de combustível tenha se tornado um campo de pesquisa maduro, estudos futuros devem explorar tecnologias emergentes e modelos preditivos híbridos para melhorar a precisão e a adaptabilidade. Esses insights contribuem para o avanço de metodologias e a orientação de futuras agendas de pesquisa em gestão de energia e formulação de políticas.*

Palavras-chave: consumo de combustível; previsão; análise bibliométrica; inteligência artificial; planejamento energético.

1 Introduction

Forecasting fuel consumption plays a critical role in resource management, public policy formulation, and tax administration. Understanding this dynamic enables more efficient management of resources and aids strategic decision-making, significantly impacting both the economy and sustainability. Within this broader context, fuel consumption analysis can be understood as part of a larger framework of forecasting methodologies. Qualitative methods, such as those based on subjective assessments, are typically employed in contexts with limited historical data, relying on subjective evaluations. In contrast, quantitative methods, including time series models and regression analysis, are widely utilized to estimate historical patterns and project future trends. Furthermore, artificial intelligence-based approaches, such as artificial neural networks, are increasingly used to enhance predictive accuracy and adapt to specific contextual details.

From another perspective, Mitrova et al. (2015) emphasize the integration of top-down methods, relying on macroeconomic variables, with bottom-up approaches, which consider detailed sector-specific data. This combined methodology is critical to addressing structural factors and contextual changes effectively. Additionally, predictive models increasingly incorporate the interplay between fossil fuels and alternative energy sources, reflecting the ongoing energy transition and the influence of public policies in this sector.

Santiago (2009) suggests that fuel consumption forecasting can employ various methodological approaches, including time series models, regression analyses, and statistical methods such as moving averages and exponential smoothing, which are particularly effective for short-term forecasts. Some studies highlight macroeconomic factors, such as Gross Domestic Product – GDP, income, and price elasticity, as significant determinants of fuel demand. In this context, Brafman (2009) underscores the importance of macroeconomic indicators like GDP and government investments in forecasting fuel consumption, given their influence on energy use.

Although several studies address fuel consumption (Le et al., 2018; Jin et al., 2021; Moshiul et al., 2022; Awan et al., 2023; Tadubana et al., 2024), a comprehensive study specifically focusing on fuel consumption forecasting remains absent, despite being an increasingly relevant research area. Such forecasting impacts not only public policy and energy planning but also consumer behavior and fuel price fluctuations.

However, despite advancements in forecasting methodologies, significant gaps remain in the literature. Most studies focus on specific approaches without providing a comprehensive perspective on global trends in fuel consumption forecasting research. Additionally, few studies explore the relationship between fuel consumption forecasts and socioeconomic factors such as changes in tax policy, energy transition, and environmental impacts. To address this gap, this study aims to conduct a bibliometric analysis of research on fuel consumption forecasting, identifying trends, scientific collaboration networks, and emerging topics. Using data from the Scopus database, the study applies bibliometric techniques to map the evolution of the field, assess the growth of scientific output, and project potential directions for future research. The primary contribution of this research is to provide a broad overview of the field, consolidating existing knowledge and highlighting opportunities for further investigation.

Based on the collected evidence, this study seeks to answer the following research question: What are the main trends and emerging fronts in fuel consumption forecasting research? By addressing this question, the paper contributes to the advancement of knowledge in the field, assisting researchers, policymakers, and energy sector managers in understanding the key directions of fuel consumption forecasting research. The bibliometric analysis revealed 5,025 documents from 1,590 sources, with an average annual growth rate of 8.64% during the period analyzed. Application of the S-curve indicated potential saturation in the research field around recent years. Geographically, publication concentrations were most notable in China, the United States, and India, reflecting a growing interest in the area and suggesting future research agenda priorities.

This study outlines research trends and identifies scientific fronts and emerging themes within the fuel consumption forecasting literature, contributing insights useful for public policy and energy management. Recognizing a trend toward research saturation, it also provides a foundation for future studies integrating broader socioeconomic and technological aspects. Hence, this research enhances understanding of current research trajectories and identifies gaps, promoting comprehensive and innovative solutions in fuel consumption forecasting.

2 Literature review

Research on the environmental, economic, and technological impacts related to fuel usage across various sectors has gained increasing importance in recent years. Numerous studies have explored trends and characteristics of alternative energy sources and their effects in sectors such as transportation, tourism, mining, and internal combustion. The reviewed literature addresses diverse approaches, from bibliometric analyses of alternative fuels research evolution and decarbonization, to forecasting fuel consumption in specific sectors. Furthermore, investigations into the effects of oil price fluctuations across different industries have become increasingly relevant. The main studies contributing to advances in these areas, including detailed insights into methodologies and significant findings, are presented below.

Leung et al. (2018) conducted a bibliometric review analyzing the relationship between fuel prices, transportation, and land use, covering 45 years of publications (1972-2017) from the Web of Science. Through citation analysis, they identified eight major research clusters, focusing especially on comparisons between cities. This methodological approach allowed mapping historical evolution, geographical trends, and main themes in the literature. Results highlighted a scarcity of interdisciplinary studies simultaneously considering these factors, emphasizing the need for further research on transport equity and accessibility in socioeconomically disadvantaged areas.

Also employing a bibliometric approach, Jin et al. (2021) investigated trends and characteristics of research on low-carbon alcohol (LCA) combustion in internal combustion engines from 2000 to 2021. Analyzing 2,250 publications from the Web of Science using tools such as CiteSpace and Biblioshiny, their results identified three distinct developmental phases, with significant growth since 2016 at an annual rate of 9.24%. China emerged as the leading producer of scientific research in this field, with studies primarily focused on combustion characteristics, engine performance, and emissions. This work provided a comprehensive overview of the state-of-the-art and emerging trends in LCA fuel research.

Focusing on maritime fuels, Moshiul et al. (2022) reviewed research trends regarding alternative fuels in response to decarbonization strategies by the International Maritime Organization (IMO). Based on 749 publications from Scopus since 1973, the authors employed R-Studio's bibliometric package and VOSviewer for quantitative and qualitative analyses. Their findings indicated a 7.05% annual growth in scientific output, with significant contributions from the USA, UK, India, and China. The research highlighted increasing attention to selecting alternative fuels, particularly through multi-criteria decision-making analyses. This study offered a comprehensive perspective on environmental, technological, and economic challenges associated with replacing traditional fuels, guiding future investigations.

Awan et al. (2023) explored the relationship between oil prices and the tourism industry, emphasizing how fluctuations in fuel costs impact tourism demand and supply. Utilizing Scopus data and visualization tools like R Studio and VOSviewer, their methodology included descriptive analyses, thematic mapping, and identification of trends related to oil price shocks. Results identified patterns and forecasted the frequency of such impacts, offering new directions for sustainable tourism research.

Finally, Tadubana et al. (2024) conducted a systematic literature review on forecasting fuel consumption techniques in open-pit mining truck operations. Analyzing 36 studies published from 2010 to 2021, they observed predictive approaches such as artificial neural networks (ANN), case-based reasoning (CBR), and mixed-integer linear programming (MILP). The results revealed payload and speed as primary parameters influencing fuel consumption forecasts. This review provided a comprehensive overview of existing methodologies and contributed to developing more efficient energy management strategies in mining.

In summary, these studies demonstrate ongoing growth in fuel research, emphasizing environmental, economic, and technological issues, especially in internal combustion engines, maritime fuels, and transportation sectors. The application of bibliometric methods is essential to identify key trends and knowledge gaps, such as a lack of interdisciplinary research and insufficient analysis of equity and accessibility in transportation. A common limitation identified in the reviewed studies is the absence of specific investigations into fuel consumption forecasting. This limitation underscores a significant opportunity for further bibliometric research focused specifically on fuel consumption forecasting, integrating these approaches more robustly and in greater detail, thus contributing to the development of more efficient and sustainable energy sector strategies.

3 Methodology

This study employs bibliographic research methodology, utilizing bibliometric research concepts based on Moresi (2021). The bibliometric approach involves systematically searching and analyzing prior publications to provide theoretical grounding and contextualize the study (Pizzani et al., 2012). To this end, a structured methodological procedure was adopted, organized into sequential stages from initial research formulation to the final analysis of results.

Initially, the research design was developed, defining the objective and constructing the search query: (forecast* OR predict*) AND "fuel consumption", aiming to identify documents specifically related to fuel consumption forecasts. The search was conducted in the Scopus database, covering publications from 2014 to 2024 and limited to documents written in English, categorized as scientific articles, conference articles, or reviews. This process resulted in a corpus consisting of 5,025 documents.

After data collection from the Scopus database, bibliometric network analysis was conducted using VOSviewer (Van Eck and Waltman, 2023) and Gephi software (Bastian, Heymann and Jacomy, 2009). VOSviewer was utilized to create initial bibliometric networks and apply vocabulary control with a specific thesaurus, reducing network nodes from 472 to 382 terms. Subsequently, Gephi software enabled analysis of the generated networks using metrics such as eigenvector centrality, degree, and triangle count, essential for identifying relevant terms, thematic clusters, and academic communities related to the topic under investigation.

Additionally, the S-curve projection technique using Loglet Lab software (Burg et al., 2017) was applied to analyze identified trends, facilitating forecasting of the future evolution of scientific production on the subject. Finally, the Bibliometrix package within R software (Aria and Cuccurullo, 2024) was employed to generate thematic maps, allowing visualization of the conceptual and intellectual structures associated with the topic and identification of basic, emerging, or declining research areas, driving forces, and specific niches representing future research opportunities.

4 Results

The analysis of conceptual and intellectual structures was conducted using the Bibliometrix package, which provides open-source tools to automate data analysis and visualization processes, facilitating bibliometric reviews (Aria and Cuccurullo, 2017). According to Table 1, the analyzed corpus obtained from the Scopus database between 2014 and 2024 comprises 5,025 documents from 1,590 different sources, showing an annual growth rate of 8.64% and an average age of 4.18 years. Each document received an average of 15.6 citations, totaling 159,478 cited references, reflecting an extensive theoretical foundation.

Table 1. Main Information about the Corpus.

Description	Results
Timespan	2014:2024
Sources (Journals, Books etc)	1,590
Documents	5,025
Annual growth rate %	8.64
Document average age	4.18
Average citations per document	15.6
References	159,478
Keywords plus (ID)	22,234
Author's keywords (DE)	11,396
Authors	15,540
Authors of single-authored documents	185
Single-authored documents	202
Co-authors per document	4.06
International co-authorships %	22.27
Article	3,287
Conference paper	1,676
Review	62

The analyzed corpus includes 11,396 author-assigned keywords and 22,234 keywords automatically generated by the system ("keywords plus"), indicating thematic diversity. Additionally, it involves 15,540 authors, averaging 4.06 co-authors per document and exhibiting an international collaboration rate of 22.27%. Scientific articles were predominant (3,287), followed by conference papers (1,676) and reviews (62).

To explore the main thematic clusters and predominant research patterns, a keyword co-occurrence network was generated using VOSviewer software (Van Eck and Waltman, 2023). This type of network graphically represents the frequency and connections between keywords, highlighting terms that frequently appear together in the analyzed documents. The network was constructed from the most relevant keywords and optimized to highlight influential terms such as “fuel consumption,” “model predictive control,” and “machine learning,” as illustrated in Figure 1.

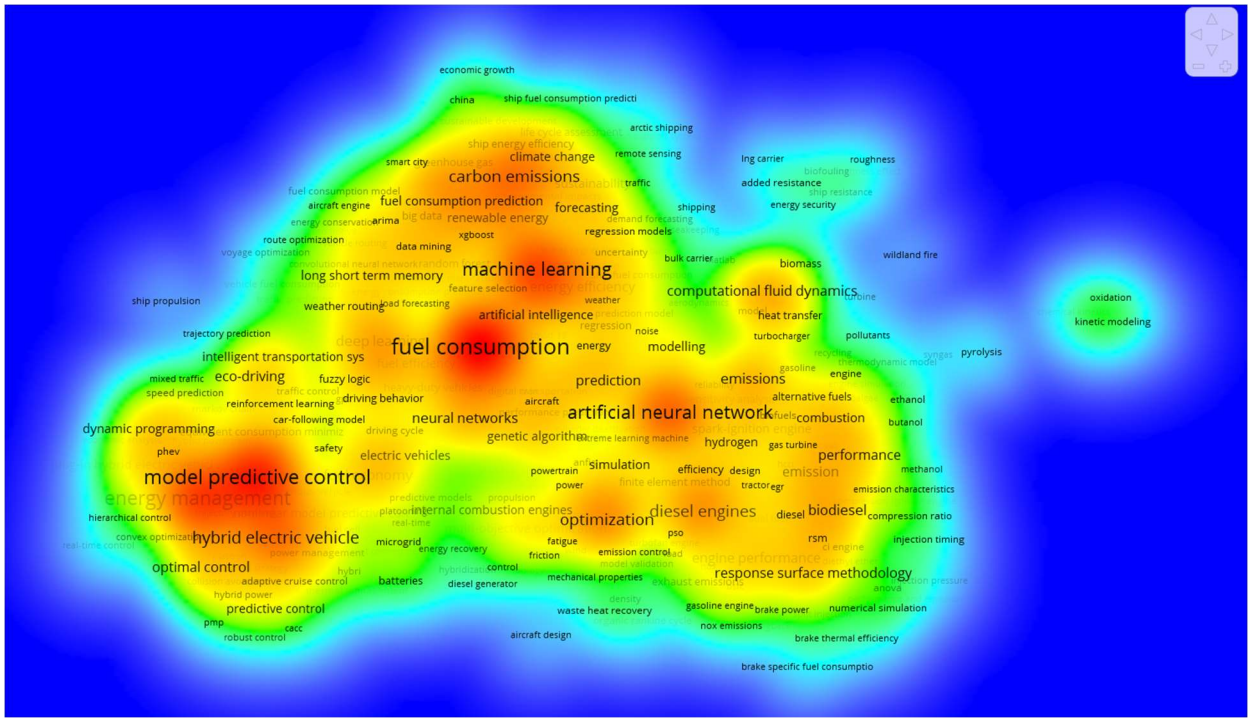

Figure 1. Keyword co-occurrence heatmap (with thesaurus).

The keyword co-occurrence network was analyzed using VOSviewer software (Van Eck and Waltman, 2023), which visually identifies relationships between terms based on their frequency of co-occurrence in the analyzed documents. In this context, Table 2 summarizes the most relevant keywords related to predictive analysis of fuel consumption, highlighting three key metrics: eigenvector centrality, degree, and triangle count. These metrics help identify terms with the highest influence and connectivity within the thematic network.

Table 2. Keyword co-occurrence network metrics.

Keyword	Eigenvector centrality	Degree	Triangle count
fuel consumption	1.00	187	1,582
machine learning	0.92	161	1,418
artificial neural network	0.89	147	1,330
optimization	0.81	133	1,132
model predictive control	0.70	114	933
hybrid electric vehicle	0.61	88	739
deep learning	0.60	82	677
diesel engines	0.59	89	681
energy management	0.59	95	727
emissions	0.58	84	659

Eigenvector centrality indicates a term's influence based on its connections within the network, with "fuel consumption" exhibiting the highest influence. Similarly, degree measures the total number of

connections, with "fuel consumption" leading with 187 connections. Lastly, the triangle count metric assesses the formation of cohesive thematic groups, with "fuel consumption" showing a high value, along with terms related to artificial intelligence such as "model predictive control" and "machine learning."

The research revealed a consistent growth in the number of publications on the topic between 2014 and 2024. Starting with 262 documents in 2019, this number gradually increased in the following years, reaching 524 publications in 2021, 535 in 2022, and peaking at 682 publications in 2023. The evolution of this increasing trend is illustrated in Figure 2.

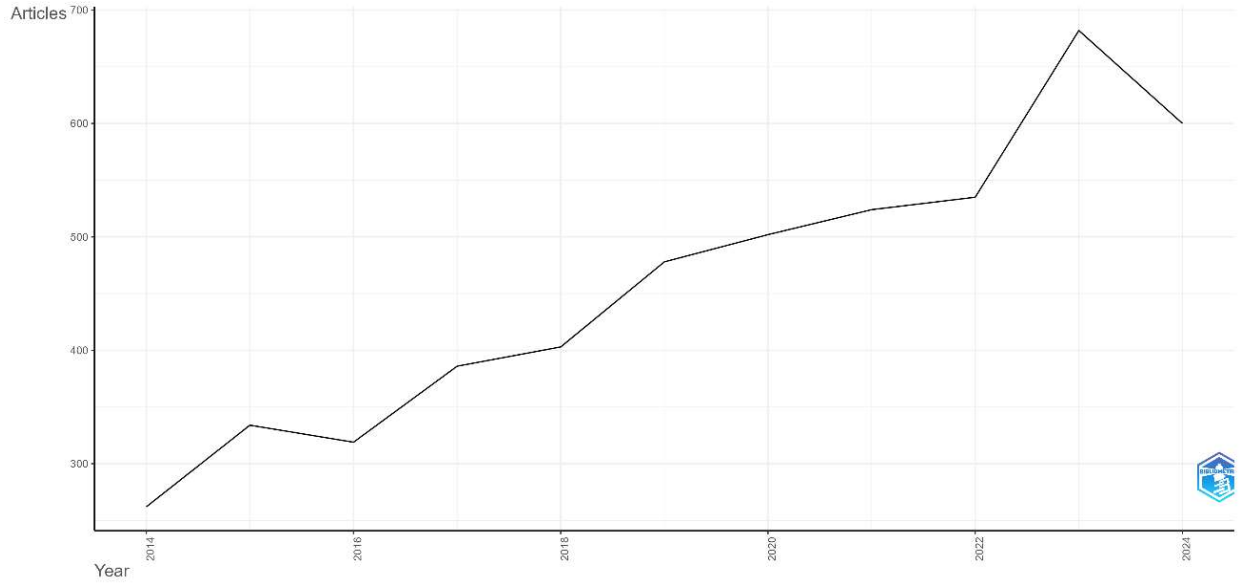

Figure 2. Annual scientific production. Source: Prepared by the author using Bibliometrix (2024).

The country-specific analysis reveals a concentration of publications primarily in Asia and North America, highlighting China as the leader in the subject with 5,013 documents, followed by the United States (2,565) and India (1,517). In Latin America, Brazil appears with 293 publications, occupying an intermediate position. This distribution is illustrated in Figure 3. These findings are corroborated by previous studies, such as Jin et al. (2021), which also identified significant scientific output in China, the United States, and India. This observation confirms that these countries maintain consolidated relevance in global academic production related to fuel consumption forecasting.

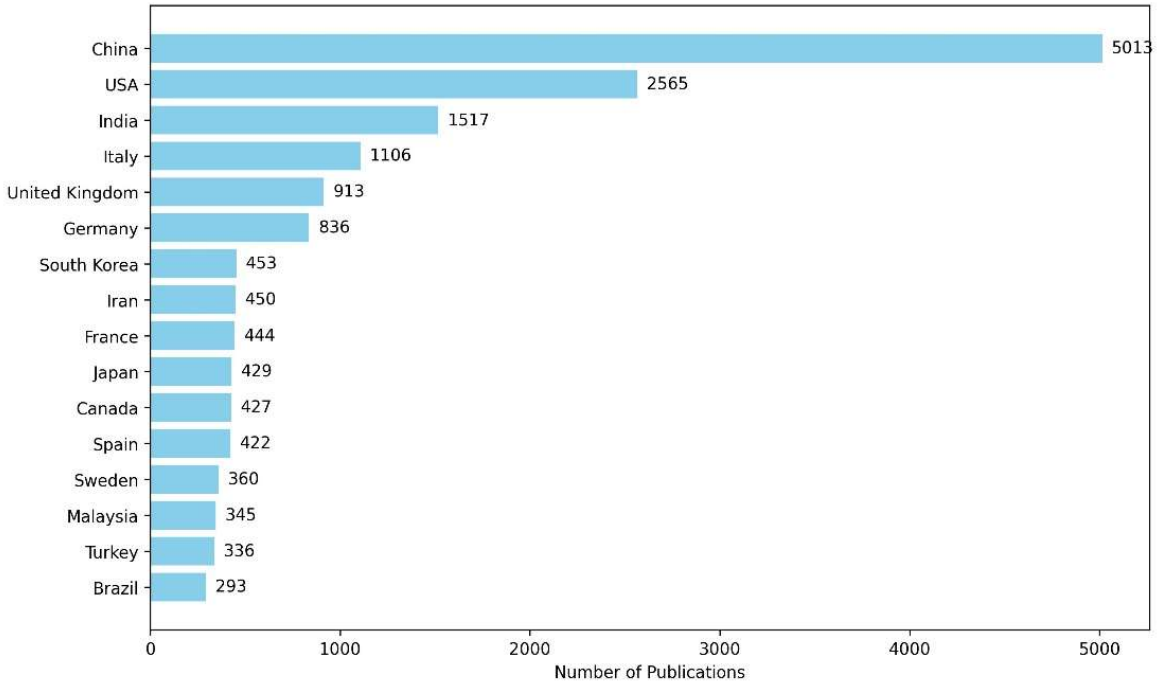

Figure 3. Countrie's scientific production.

Table 3 presents studies with the highest global citations. Yang et al. (2014) lead with 1,075 citations, analyzing thermal comfort and energy efficiency in buildings, concluding that higher indoor temperatures can reduce energy consumption. Another prominent work by Holmberg et al. (2014), cited 374 times, addresses frictional impacts on fuel consumption in heavy vehicles, while Tezdogan et al. (2015) examine wave-induced resistance on ships at low speeds. Research on vehicle platooning techniques was discussed by Li et al. (2017) and Turri et al. (2016), exploring convoy coordination and its potential to reduce fuel consumption. Additionally, studies applied to building energy efficiency have gained prominence, exemplified by Seyedzadeh et al. (2018), who utilized artificial intelligence to enhance energy performance and reduce emissions.

Table 3. Most globally cited documents.

Document	Topic	Global Citations
Yang, L., Yan, H., Lam, Joseph C. (2014). Thermal comfort and building energy consumption implications – A review.	Thermal Comfort and Energy Efficiency	1,075
Geertsma, R.D., Negenborn, R.R., Visser, K., Hopman, J.J. (2017). Design and control of hybrid power and propulsion systems for smart ships: A review of developments.	Hybrid Propulsion Systems for Ships	422
Holmberg, K., Andersson, P., Nylund, N.O., Makela, K., Erdemir, A. (2014). Global energy consumption due to friction in trucks and buses.	Friction Reduction in Heavy-Duty Vehicles	374
Tezdogan, T., Demirel, Y. K., Kellet, P., Khorasanchi, M., Incecik, A., Turan, O. (2015). Full-scale unsteady RANS CFD simulations of ship behaviour and performance in head seas due to slow steaming.	Ship Energy Efficiency in Waves	360
Liu, T., Hu, X., Li, S., Cao, D. (2017). Reinforcement Learning Optimized Look-Ahead Energy Management of a Parallel Hybrid Electric Vehicle.	Predictive Energy Management in HEVs	343
Wang, Y., Gan, D., Sun, M., Zhang, N., Lu, Z., Kang, C. (2019). Probabilistic individual load forecasting using pinball loss guided LSTM.	Probabilistic Individual Load Forecasting	322
Li, S. E., Zheng, Y., Li, K., Wu, Y., Hedrick, J. K., Gao, F., and Zhang, H. (2017). Dynamical modeling and distributed control of connected and automated vehicles.	Distributed Control of Connected Vehicles	322
Turri, V., Besselink, B., and Johansson, K. H. (2016). Cooperative Look-Ahead Control for Fuel-Efficient and Safe Heavy-Duty Vehicle Platooning	Cooperative Control for Truck Platooning	314
Seyedzadeh, S., Pour Rahimian, F., Glesk, I., and Roper, M. (2018). Machine learning for estimation of building energy consumption and performance: a review.	Machine Learning for Building Energy Efficiency	301
Sun, C., Sun, F., and He, H. (2016). Investigating adaptive-ECMS with velocity forecast ability for hybrid electric vehicles.	Velocity Forecasting for Energy Management in HEVs	298

The concept of local citations, in this analysis, refers to references made among documents within the analyzed corpus, enabling the identification of direct influences and internal thematic connections. In this context, studies focusing primarily on optimizing fuel consumption through predictive techniques and advanced analytical methods, particularly in the maritime sector, stand out. Relevant examples include the article by Wang et al. (2018), proposing a regression model to forecast fuel consumption in ships; Coraddu et al. (2017), who developed a method aimed at improving estimation accuracy; and Jeon et al. (2018), utilizing artificial intelligence-based approaches.

Additionally, research such as Sun et al. (2016), Lu et al. (2015), and Hu et al. (2019) prominently explore specific strategies for maritime fuel optimization, ranging from operational efficiency and route optimization to predictive models that consider actual navigation conditions. Other studies extend this perspective, including Zhou et al. (2016), reviewing models applicable to various contexts, and Zi et al. (2016), which focuses on forecasting and optimizing fuel consumption in hybrid vehicles by accounting for driver behaviors and traffic conditions.

Table 4. Most locally cited documents.

Document	Topic	Local Citations	Global Citations
Wang, S., Ji, B., Zhao, J., Liu, W., Xu, T. (2018). Predicting ship fuel consumption based on LASSO regression	Ship Fuel Consumption Forecasting	51	156
Coraddu, A., Oneto, L., Baldi, F., Anguita, D. (2017). Vessels fuel consumption forecast and trim 47ptimization: A data analytics perspective.	Ship Fuel Consumption Forecasting and Optimization	51	148
Jeon, M., Noh, Y., Shin, Y., Lim, O., Lee, I., Cho, D. (2018). Prediction of ship fuel consumption by using an artificial neural network.	Ship Fuel Consumption Forecasting	39	74
Turri, V., Besselink, B., Johansson, K. H. (2016). Cooperative Look-Ahead Control for Fuel-Efficient and Safe Heavy-Duty Vehicle Platooning	Cooperative Control for Truck Platooning	34	314
Zhou, M., Jin, H., Wang, W. (2016). A review of vehicle fuel consumption models to evaluate eco-driving and eco-routing.	Vehicle Fuel Consumption Modeling	33	229
Lu, R., Turan, O., Boulougouris, E., Banks, C., Incecik, A. (2015). A semi-empirical ship operational performance prediction model for voyage optimization towards energy efficient shipping.	Ship Operational Performance Forecasting	33	138
Li, L., You, S., Yang, C., Yan, B., Song, J., Chen, Z. (2016). Driving-behavior-aware stochastic model predictive control for plug-in hybrid electric buses.	Energy Management Strategy for Hybrid Buses	27	236
Le, L. T., Lee, G., Park, K. S., Kim, H. (2020). Neural network-based fuel consumption estimation for container ships in Korea.	Ship Fuel Consumption Forecasting	27	60
Sun, C., Sun, F., He, H. (2016). Investigating adaptive-ECMS with velocity forecast ability for hybrid electric vehicles.	Speed Forecasting for Energy Management in HEVs	26	298
Hu, Z., Jing, Y., Hu, Q., Sen, S., Zhou, T., Osman, M. T. (2019). Prediction of fuel consumption for enroute ship based on machine learning.	Ship Fuel Consumption Forecasting	25	54

In the Brazilian literature, the study by Cabral et al. (2017) stands out with the highest number of global citations (83), proposing a spatiotemporal model based on spatial econometrics to forecast electricity consumption in the country. Another significant contribution is the work of Ibarra-Espinosa et al. (2019), which uses GPS-based traffic data and travel demand models to predict vehicle emissions in urban areas of southeastern Brazil. Complementing this regional approach, Vidoza et al. (2016) investigated future scenarios for fossil fuel use in electricity generation in Venezuela, while Taheri-Garavand et al. (2022) applied artificial neural networks to predict fuel consumption efficiency in internal combustion engines.

Furthermore, the R-Bibliometrix package enables the creation of keyword co-occurrence networks and their relation to the thematic map proposed by Callon, Courtial, and Laville (1991). In this map, keywords are represented as concepts and categorized according to centrality measures (relevance of the theme in the broader context) and density (degree of internal development of the theme). The results are visualized in a two-dimensional conceptual diagram, divided into four strategic quadrants: (1) emerging or declining themes (bottom left), (2) niche themes (top left), (3) basic themes (bottom right), and (4) motor themes (top right). This approach was applied to the 11,396 author-assigned keywords, resulting in the thematic map presented in Figure 4.

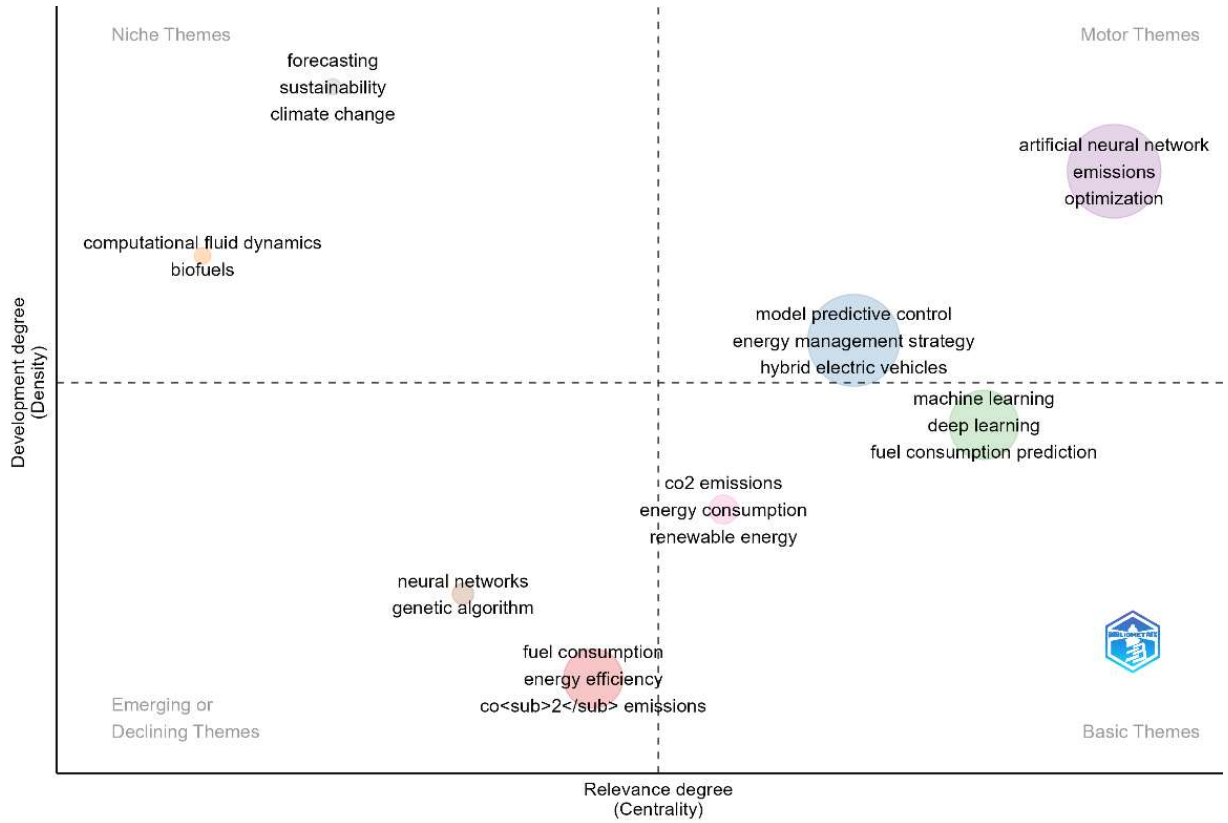

Figure 4. Thematic Map. Source: Prepared by the authors using Bibliometrix (2024).

Basic themes, such as "renewable energy," "fuel consumption forecasting," and "machine learning," exhibit high centrality and low density, indicating broad relevance in the literature while still having relatively underdeveloped internal structures. In contrast, motor themes display both high centrality and high density, reflecting their significance and maturity within the research field, with "artificial neural networks" and "hybrid electric vehicles" standing out as key technological innovations.

Conversely, themes positioned in the lower-left quadrant exhibit low centrality and density, representing either declining or emerging areas, such as "genetic algorithm" and "energy efficiency," which offer opportunities for future research. Lastly, niche themes demonstrate high density but low centrality, indicating well-developed internal structures yet limited connection to the research core. This category includes topics such as "sustainability," "climate change," and "biofuels."

Finally, the S-curve analysis reveals that the topic of "fuel consumption forecasting" has shown consistent growth in recent years. This model describes the evolutionary cycle of scientific production in three main phases: slow initial growth, accelerated expansion, and subsequent stabilization (Chen, Chen and Lee, 2010; Ernst, 1997). The cumulative publication data from 2014 to 2023 were modeled using the Loglet Lab 4 tool (Burg et al., 2017).

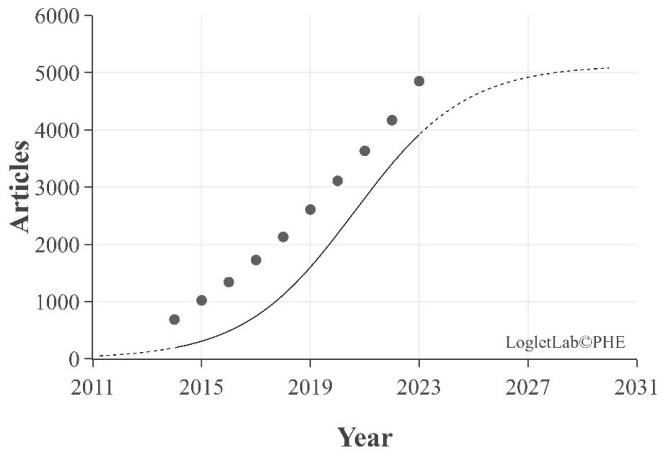

Figure 5. Topic growth estimate. Source: Prepared by the authors using Loglet Lab (2024).

The model estimated a maximum capacity (K) of 5,133 publications, indicating that the inflection point, the period of highest growth, occurred in 2021. This result reflects significant maturation of the topic over the past decade, consolidating its importance in the scientific literature. Additionally, projections suggest that the topic will reach saturation around 2030, marking the beginning of its academic maturity phase.

5 Final considerations

Fuel consumption forecasting plays a key role in energy planning, public policy formulation, and global economic management. This study conducted a comprehensive bibliometric analysis of research on fuel consumption forecasting, identifying trends, scientific collaboration networks, and emerging research fronts within this field. By analyzing 5,025 documents from the Scopus database, it was possible to map the growth of academic production, identify key research hubs, and assess the predominant methodologies used for fuel consumption forecasting.

The main findings indicate that scientific output in this field has exhibited an average annual growth rate of 8.64%, with a geographical concentration in countries such as China, the United States, and India. The keyword co-occurrence analysis revealed that artificial intelligence and machine learning techniques are increasingly prevalent in fuel consumption forecasting studies, gradually replacing traditional methodologies based solely on time series and statistical regression models. Furthermore, the application of the S-curve projection suggested that the field may reach a saturation point by approximately 2030, emphasizing the need for interdisciplinary approaches and innovative methodologies to drive further advancements.

The research also highlighted the influence of macroeconomic factors such as GDP, fuel price elasticity, and government investments on forecasting models. Recent studies suggest that incorporating these factors into predictive models can significantly enhance the accuracy of projections, enabling more robust analyses of future fuel demand. However, a gap remains in studies integrating big data, real-time analytics, and the interrelationship between fossil fuels and renewable energy sources in forecasting methodologies.

Given these findings, this study offers significant contributions to the field of fuel consumption forecasting. First, by consolidating a detailed overview of research trends, it provides valuable insights for academics and policymakers seeking to understand the primary directions of knowledge in this area. Additionally, the bibliometric analysis conducted allows for the identification of research gaps and opportunities, encouraging the development of novel hybrid models that combine artificial intelligence, socioeconomic factors, and real-time data analysis.

For future research, it is recommended to explore emerging topics such as the application of deep neural networks, remote sensing, blockchain-based forecasting models, and dynamic fuel pricing systems. Furthermore, it would be relevant to investigate how energy transition policies and incentives for vehicle electrification impact fossil fuel demand in the medium and long term.

In conclusion, this study reinforces the importance of fuel consumption forecasting as a well-established yet evolving research field. The integration of more sophisticated and interdisciplinary approaches can lead to more accurate forecasts that align with the global dynamics of the energy sector. Consequently, future research is expected to advance toward more efficient predictive models capable of supporting both economic management and the formulation of sustainable public policies in the energy sector.

Bibliographic references

Ackermann, AE and Sellitto, MA (2022) ‘Métodos de previsão de demanda: uma revisão da literatura’, *Innovar*, vol. 32, no. 85, pp. 83-99. https://doi.org/10.15446/innovar.v32n85.100979.

Aria, M and Cuccurullo, C (2024) *Package ‘bibliometrix’*. Available at: https://cran.r-project.org/web/packages/bibliometrix/bibliometrix.pdf [Accessed 6 Nov. 2024].

Awan, A, Bibi, M, Bano, F and Shoukat, S (2023) ‘A bibliometric analysis on fuel prices fluctuations and tourism under the era of sustainable development’, *Pakistan Journal of Humanities and Social Sciences*, vol. 11, no. 2, pp. 792–813. https://doi.org/10.52131/pjhss.2023.1102.0392.

Bastian, M, Heymann, S and Jacomy, M (2009) 'Gephi: an open source software for exploring and manipulating networks', in *Proceedings of the 3rd International AAAI Conference on Weblogs and Social Media*, pp. 361-362.

Brafman, I (2009) *Modelo econométrico para a projeção do consumo aparente de combustível no Brasil – Otto e Diesel*. Master's thesis, IBMEC, Rio de Janeiro.

Burg, D, Schachter, E, Meyer, P and Ausubel, J (2024) *Loglet Lab (Version 4.0) [Software]*. Available at: http://logletlab.com [Accessed 20 Nov. 2024].

Cabral, JA, Legey, LFL and Cabral, MVF (2017) 'Electricity consumption forecasting in Brazil: a spatial econometrics approach', *Energy*, vol. 134, pp. 125-139. https://doi.org/10.1016/j.energy.2017.03.005.

Callon, M, Courtial, JP and Laville, F (1991) 'Co-word analysis as a tool for describing the network of interactions between basic and technological research: the case of polymer chemistry', *Scientometrics*, vol. 22, no. 1, pp. 155-205.

Chen, YH, Chen, CY and Lee, SC (2010) 'Technology forecasting of new clean energy: the example of hydrogen energy and fuel cell', *African Journal of Business Management*, vol. 4, no. 7, pp. 1372-1380.

Coraddu, A, Oneto, L, Baldi, F and Anguita, D (2017) 'Vessels fuel consumption forecast and trim optimisation: a data analytics perspective', *Ocean Engineering*, vol. 130, pp. 351-370. https://doi.org/10.1016/j.oceaneng.2016.11.058

Ernst, H (1997) 'The use of patent data for technological forecasting: the diffusion of CNC technology in the machine tool industry', *Small Business Economics*, vol. 9, no. 4, pp. 361-381.

Geertsma, RD, Negenborn, RR, Visser, K and Hopman, JJ (2017) 'Design and control of hybrid power and propulsion systems for smart ships: a review of developments', *Applied Energy*, vol. 194, pp. 30–54.

Holmberg, K, Andersson, P, Nylund, N-O, Mäkelä, K and Erdemir, A (2014) 'Global energy consumption due to friction in trucks and buses', *Tribology International*. https://doi.org/10.1016/j.triboint.2014.05.004.

Hu, Z, Jing, Y, Hu, Q, Sen, S, Zhou, T and Osman, MT (2019) 'Prediction of fuel consumption for enroute ship based on machine learning', *IEEE Access*, vol. 7, pp. 1-1. https://doi.org/10.1109/ACCESS.2019.2933630.

Ibarra-Espinosa, S, Ynoue, RY, Ropkins, K, Zhang, X and De Freitas, ED (2019) 'High spatial and temporal resolution vehicular emissions in south-east Brazil with traffic data from real-time GPS and travel demand models', *Atmospheric Environment*, no. 117136. https://doi.org/10.1016/j.atmosenv.2019.117136.

Jeon, M, Noh, Y, Shin, Y, Lim, O, Lee, I and Cho, D (2018) 'Prediction of ship fuel consumption by using an artificial neural network', *Journal of Mechanical Science and Technology*, vol. 32, no. 12, pp. 5785–5796. https://doi.org/10.1007/s12206-018-1126-4.

Jin, C, Ampah, JD, Afrane, S, et al. (2022) 'Low-carbon alcohol fuels for decarbonizing the road transportation industry: A bibliometric analysis 2000–2021', *Environmental Science and Pollution Research*, vol. 29, pp. 5577–5604. https://doi.org/10.1007/s11356-021-15539-1.

Le, LT, Lee, G, Park, KS and Kim, H (2020) 'Neural network-based fuel consumption estimation for container ships in Korea', *Maritime Policy and Management*, vol. 47, no. 4, pp. 467–483. https://doi.org/10.1080/03088839.2020.1729437.

Leung, A, Burke, M, Cui, J and Perl, A (2018) 'Fuel price changes and their impacts on urban transport – A literature review using bibliometric and content analysis techniques, 1972–2017', *Transport Reviews*, vol. 39, no. 4, pp. 463–484. https://doi.org/10.1080/01441647.2018.1523252.

Li, L, You, S, Yang, C, Yan, B, Song, J and Chen, Z (2016) 'Driving-behavior-aware stochastic model predictive control for plug-in hybrid electric vehicles', *Applied Energy*, vol. 162, pp. 868–879. https://doi.org/10.1016/j.apenergy.2015.10.152.

Li, SE, Zheng, Y, Li, K, Wu, Y, Hedrick, JK, Gao, F and Zhang, H (2017) 'Dynamical modeling and distributed control of connected and automated vehicles: challenges and opportunities', *IEEE Transactions on Intelligent Transportation Systems*, vol. 18, no. 10, pp. 2680–2694. https://doi.org/10.1109/MITS.2017.2709781.

Liu, T, Hu, X, Li, SE and Cao, D (2017) 'Reinforcement learning optimized look-ahead energy management of a parallel hybrid electric vehicle', *IEEE Transactions on Vehicular Technology*, vol. 66, no. 12, pp. 10673-10684. https://doi.org/10.1109/TVT.2017.2752578.

Lu, R, Turan, O, Boulougouris, E, Banks, C and Incecik, A (2015) 'A semi-empirical ship operational performance prediction model for voyage optimization towards energy efficient shipping', *Ocean Engineering*, vol. 110, pp. 18–28. https://doi.org/10.1016/j.oceaneng.2015.07.042.

Mitrova, T, Kulagin, V, Grushevenko, D, Grushevenko, E and Galkina, A (2015) 'Integrated method of petroleum products demand forecasting considering economic, demographic and technological factors', *Economics and Business Letters*, vol. 4, no. 3, pp. 98-107.

Moresi, EAD and Pinho, I (2021) 'Proposta de abordagem para refinamento de pesquisa bibliográfica', *New Trends in Qualitative Research*, vol. 9, pp. 11–20. https://doi.org/10.36367/ntqr.9.2021.11-20.

Moshiul, AM, Mohammad, R, Hira, FA and Maarop, N (2022) 'Alternative marine fuel research advances and future trends: A bibliometric knowledge mapping approach', *Sustainability*, vol. 14, no. 9, p. 4947. https://doi.org/10.3390/su14094947.

Pizzani, L, Silva, RCB and Hayashi, CRM (2012) 'A pesquisa bibliográfica na produção científica: contextualização e princípios básicos para sua realização', *RDBCI: Revista Digital de Biblioteconomia e Ciência da Informação*, vol. 10, no. 2, pp. 53-66. https://periodicos.sbu.unicamp.br/ojs/index.php/rdbci/article/view/2037.

Santiago, FS (2009) *Um modelo econométrico + insumo-produto para a previsão de longo prazo da demanda de combustíveis no Brasil*, Dissertação (Mestrado em Economia Aplicada), Universidade Federal de Juiz de Fora.

Seyedzadeh, S, Pour Rahimian, F, Glesk, I and Roper, M (2018) 'Machine learning for estimation of building energy consumption and performance: a review', *Visualization in Engineering*, vol. 6, no. 5, pp. 1–20. https://doi.org/10.1186/s40327-018-0064-7.

Sun, C, Sun, F and He, H (2016) 'Investigating adaptive-ECMS with velocity forecast ability for hybrid electric vehicles', *Applied Energy*, vol. 177, pp. 250–259. https://doi.org/10.1016/j.apenergy.2016.02.026.

Tadubana, G, Sigweni, B and Ayoung, DA (2024) 'Systematic review on prediction of haulage truck fuel consumption in open-pit mines', *International Journal of Mining, Reclamation and Environment*, vol. 38, no. 10, pp. 833–850. https://doi.org/10.1080/17480930.2024.2357509.

Taheri-Garavand, A, Heidari-Maleni, A, Mesri-Gundoshmian, T and Samuel, OD (2022) 'Application of artificial neural networks for the prediction of performance and exhaust emissions in IC engine using biodiesel-diesel blends containing quantum dot based on carbon doped', *Energy Conversion and Management: X*, vol. 16, p. 100304. https://doi.org/10.1016/j.ecmx.2022.100304.

Tezdogan, T, Demirel, YK, Kellett, P, Khorasanchi, M, Incecik, A and Turan, O (2015) 'Full-scale unsteady RANS CFD simulations of ship behaviour and performance in head seas due to slow steaming', *Ocean Engineering*, vol. 97, pp. 186–206. https://doi.org/10.1016/j.oceaneng.2015.01.011.

Turri, V, Besselink, B and Johansson, KH (2016) 'Cooperative look-ahead control for fuel-efficient and safe heavy-duty vehicle platooning', *IEEE Transactions on Control Systems Technology*, vol. 25, no. 1, pp. 12–28. https://doi.org/10.1109/TCST.2016.2542044.

Van Eck, NJ and Waltman, L (2023) *VOSviewer manual*, Leiden, [s.n.].

Vidoza, JA and Gallo, WLR (2016) 'Projection of fossil fuels consumption in the Venezuelan electricity generation industry', *Energy*, vol. 104, pp. 237–249. https://doi.org/10.1016/j.energy.2016.03.130.

Wang, S, Ji, B, Zhao, J, Liu, W and Xu, T (2017) 'Predicting ship fuel consumption based on LASSO regression', *Transportation Research Part D: Transport and Environment*, vol. 57, pp. 22–32. https://doi.org/10.1016/j.trd.2017.09.014.

Wang, Y, Gan, D, Sun, M, Zhang, N, Lu, Z and Kang, C (2019) 'Probabilistic individual load forecasting using pinball loss guided LSTM', *Applied Energy*, vol. 235, pp. 10–20. https://doi.org/10.1016/j.apenergy.2018.10.078.

Yang, L, Yan, H and Lam, JC (2014) 'Thermal comfort and building energy consumption implications – a review', *Applied Energy*, vol. 115, pp. 164–173. https://doi.org/10.1016/j.apenergy.2013.10.062.

Zhou, M, Jin, H and Wang, W (2016) 'A review of vehicle fuel consumption models to evaluate eco-driving and eco-routing', *Transportation Research Part D: Transport and Environment*, vol. 49, pp. 203–218. https://doi.org/10.1016/j.trd.2016.09.008.