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Making road freight transport more Sustainable: Insights from a systematic literature review

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A R T I C L E I N F O

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Stakeholder role in freight transportation sustainability

A B S T R A C T

Road-based transportation being the most used transport mode globally has associated negative externalities such as traffic accidents, higher product costs, greenhouse gas emissions, air and noise pollution necessitating improvement. The study aims to provide a comprehensive overview of state-of-the-art knowledge about improving road freight transportation sustainability (RFTS) and discuss ways key stakeholders can do for its improvement. Therefore, the study adds to the existing reviews by providing more insights and a nuanced appreciation of improving RFTS. This is of relevance to policymakers, practitioners, and other key actors in the road-based freight transportation sector. The study utilized a meta-aggregation approach involving 75 peer-reviewed articles. Three themes under which RFTS can be addressed, namely (1) policy and regulation-based measures, (2) logistics and transportation efficiency-based measures, and (3) innovative technology-based measures were identified. Furthermore, the study found that the successful attainment of RFTS depends on the cooperative nature of both direct and indirect actors, strengthening of existing laws, capital investment, and stakeholder demands and pressure. However, less focus on stakeholder collaboration was observed to achieve the needed benefits for all three sustainability aspects. The study has limitations as only peer-reviewed articles were utilized. Other literature types including books would have provided a wider view of the topic. Further research area could examine how concepts like collaboration, cooperation, and coopetition affect the three sustainability perspectives.

Introduction

The transportation system is recognized as the lifeblood of modern societies (Engström, 2016; Stenico de Campos et al., 2019). Roads, an integral part of this system, are used for short and long-distance goods delivery using vehicles (Engström, 2016). Freight transportation by road is widely used due to its flexibility (Dadsena et al., 2019; Rotaris et al., 2022), reliability (Dadsena et al., 2019; Demir et al., 2015), and speedy delivery (Jarašūnienė et al., 2022). Within the European Union, road freight transportation (RFT) constitutes about 76 % of inland freight transport, measured in tonne-kilometers (Eurostat, 2021). Moreover, RFT is estimated to increase by 40 % by 2030, and a little more than 80 % by 2050 (European Commission, 2021; Rotaris et al., 2022).

However, RFT generates negative externalities such as air and water pollution, congestion, noise pollution, and traffic accidents (Nocera et al., 2018; Stenico de Campos et al., 2019). Hence, the sustainability of RFT is increasingly being questioned by researchers, stakeholders, and policymakers as they aim to meet sustainable development goals (SDGs) by 2030 and achieve climate neutrality by 2050. According to Kumar et al. (2019), businesses need to shift from the traditional objective of minimizing total operating costs to the broader objective of sustainability. To achieve this broader objective, there is a need for knowledge on how to reduce the negative externalities caused by RFT.

Although research abounds on the topic, it tends to be scattered, with a narrow focus. Lagorio et al. (2020), for example, reviewed the adoption of new technologies by the management of logistics companies. In another review, Ahmad et al. (2022) focused on the identification and assessment of interventions meant to improve space utilization during packaging in freight transport to achieve economic and environmental benefits. It was established that the retail leg of the supply chain performs more packaging-related improvements than other partners in the supply chain. Aloui et al. (2021) reviewed collaborative sustainable transportation and maintained that the social aspect of sustainable development within the area of collaborative network optimization has received little attention. Other reviews focused mainly on the environmental effects of road freight transportation sustainability (RFTS)

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(Demir et al., 2014; Evangelista et al., 2018; Patella et al., 2020; Ren et al., 2019). Collaço et al. (2022) studied how knowledge from road freight transportation literature contributes to the sustainable development goals (SDGs) attainment focusing on environmental, economic, and technical studies. They found that the SDGs were not prioritized by included papers and recommended further studies among others 2,3,7,9,11,12,13 and 17.

As a result, Pathak et al. (2019) stressed that the quest for sustainable freight transportation requires a balance between the economic, social, and environmental dimensions of the supply chain. They further identified a lack of coordination among key stakeholders as one of the main challenges to realizing sustainable freight transport systems. Oberhofer and Fürst (2012) found that companies are aware that RFTS is crucial yet needs improvement in actual performance.

Although research has investigated various aspects of RFTS, no single study has, to the best of the author's knowledge, taken a broad approach to the topic and broadly investigated the concept of RFTS in all three aspects, namely social, environmental, and economic sustainability. This study aimed to fill this gap. Furthermore, this study aimed to establish new evidence-based insights on how stakeholders can make RFT more sustainable and to propose areas for future research. More specifically, the aim of this study was threefold:

1. To assess developments in the literature on RFTS to identify
   a. how the publication frequency of articles on this topic has evolved in the last decade,
   b. the scientific journals that have been most involved in this topic,
   c. which aspects of RFTS have been focused on most,
   d. the geographical distribution of the papers, and
   e. the research methods that have been used
2. To identify measures that can improve RFTS
3. To determine what RFT stakeholders can do to improve RFTS

The study contributions are threefold: the study (a) adds to the strands of literature reviews by focusing on all three aspects namely economic, social, and environmental sustainability. (b) identifies measures different stakeholders can consider to improve RFTS, and (c) identifies research gaps for future research.

The remainder of this paper is organized as follows: Section 2 outlines the study methodology; Section 3 presents the main findings; Section 4 provides a discussion; Section 5 provides concluding remarks and suggestions for future research.

Methodology

The review utilized *meta*-aggregation (Lockwood et al., 2015). Meta-aggregative reviews aim to inform practice and synthesize findings from the included studies, based on pragmatism and Husserlian transcendental phenomenology, into reduced categories (Lockwood et al., 2015). This approach is appropriate for the study as it focuses on measures that can be implemented by different categories of stakeholders to improve the sustainability of RFT.

The steps followed in the review are based on internationally recognized procedures (See e.g., Aromataris & Pearson, 2014; Durach et al., 2017):

1. Establishing the research purpose and research questions
2. Deciding on inclusion and exclusion criteria
3. Selection of relevant papers
4. Analysis and results synthesis
5. Reporting of the results

Establishing the research purpose and research questions

The *meta*-aggregative systematic review began with the creation of a review protocol that defines the objective, method, and scheme for the review (Lockwood et al., 2015). Before the study, a review protocol was presented to other researchers (See A ppendix A for the review protocol). The researchers included senior academics with expertise in transportation, logistics, and supply chain management (3), data analysts (1), and PhD scholars in transportation studies (3). These researchers provided constructive comments which culminated in the present article. Supporting information.

Deciding inclusion and exclusion criteria

The study focused on articles published in the last decade, from 2013 to 2022. The study excluded rail, water, and air transport and papers related to corporate and ecological sustainability. The 'ecological sustainability' relates to biodiversity that may be affected by road freight transportation activities. The 'corporate sustainability' concerns ensuring stakeholder value from business strategies that go beyond the three aspects of sustainability by including issues of ethics, and cultural considerations. The environmental perspective in this study is about the direct consequences of road-based transportation externalities such as GHG emissions, noise pollution, and other pollutants. The study purposely used peer-reviewed articles to ensure homogeneity in the corpus (Lagorio et al., 2022; Tranfield et al., 2003) and due to the general quality of the analysis after being subjected to the rigorous review process (David & Han, 2004). Therefore, books, conference papers, reports, data papers, etc. were excluded. The search was limited to articles published in English, which many consider the language of science (Huttner, 2008).

The two main databases considered were Scopus and Web of Science (WoS). Scopus was chosen because it is considered the world's largest abstract and citation database (Vila et al., 2020), and WoS is labeled the "gold standard" for citation analysis (Falagas et al., 2008; Harzing & Alakangas, 2016, p. 791). Further checks revealed many of these papers were in Google Scholar. Simple and Boolean search methods were used based on the identified keywords. This helped to develop search strings using multiple synonyms (Kembro & Näslund, 2014). The search was conducted in March 2023. The search strings should demonstrate replicability (Tranfield et al., 2003), with an asterisk (*) added to a word for multiple variations of the word. The main search strings, keywords, and Boolean logic to combine keywords were "road freight transport*" or "road goods transport" or "last mile deliver*" and "sustain*"; "urban freight transport*" and "sustain*"; "urban freight transport*" or "last mile logistics" and "sustain*"; "road sustain*"; "environmental sustain*"; "social freight sustain*"; "economic freight sustain*"; "freight transport improve*"; "road sustain*"; "road freight sustain*"; "road freight transport*"; "sustain* road".

Selection of relevant papers for the study

The search returned 236 articles from Scopus and 137 articles from WoS, totaling 373 articles. These articles were imported into a spreadsheet for further analysis where 136 duplicates were removed. The remaining abstracts were carefully read, resulting exclusion of 179 articles mostly out of scope. 58 remaining articles were read in full to determine their relevance for inclusion (Durach et al., 2017). Finally, backward and forward snowballing (Lagorio & Pinto, 2021) was conducted to identify an additional 17 relevant articles. Ultimately, 75 full-length articles were considered relevant to the study.

The process of identifying relevant articles is illustrated in the flowchart in Fig. 1.

Analysis and results synthesis

The *meta*-aggregation was done in four main steps. In the first step, relevant information was extracted to obtain an overview of the data set (Frimpong et al., 2022). This included the transportation distance focus,

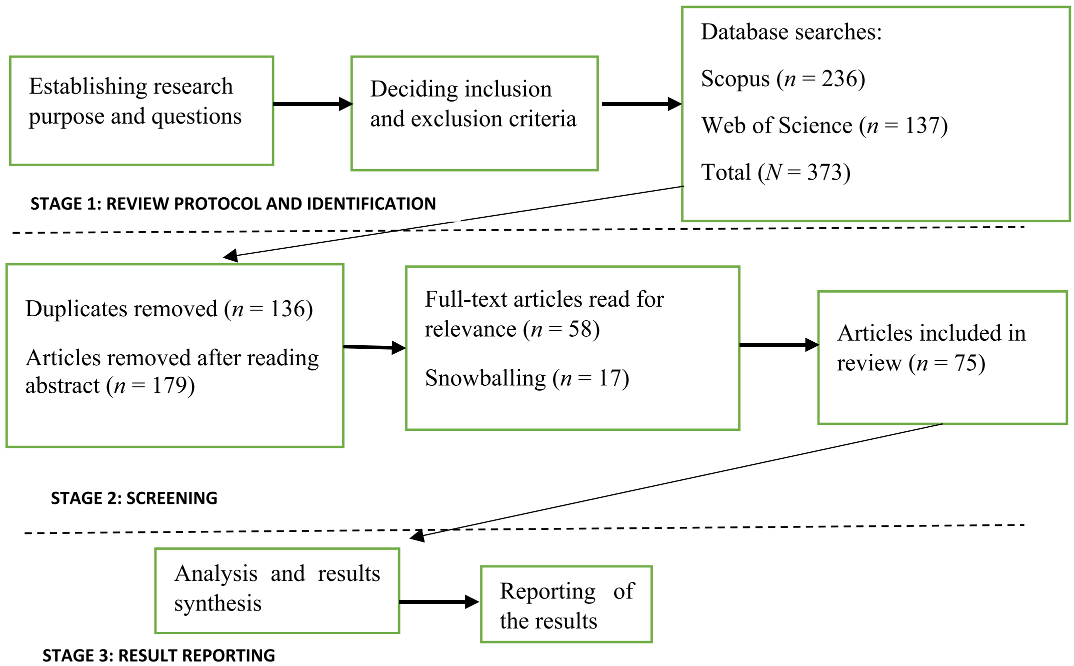

Fig. 1. Flowchart of the search strategy and reporting process.

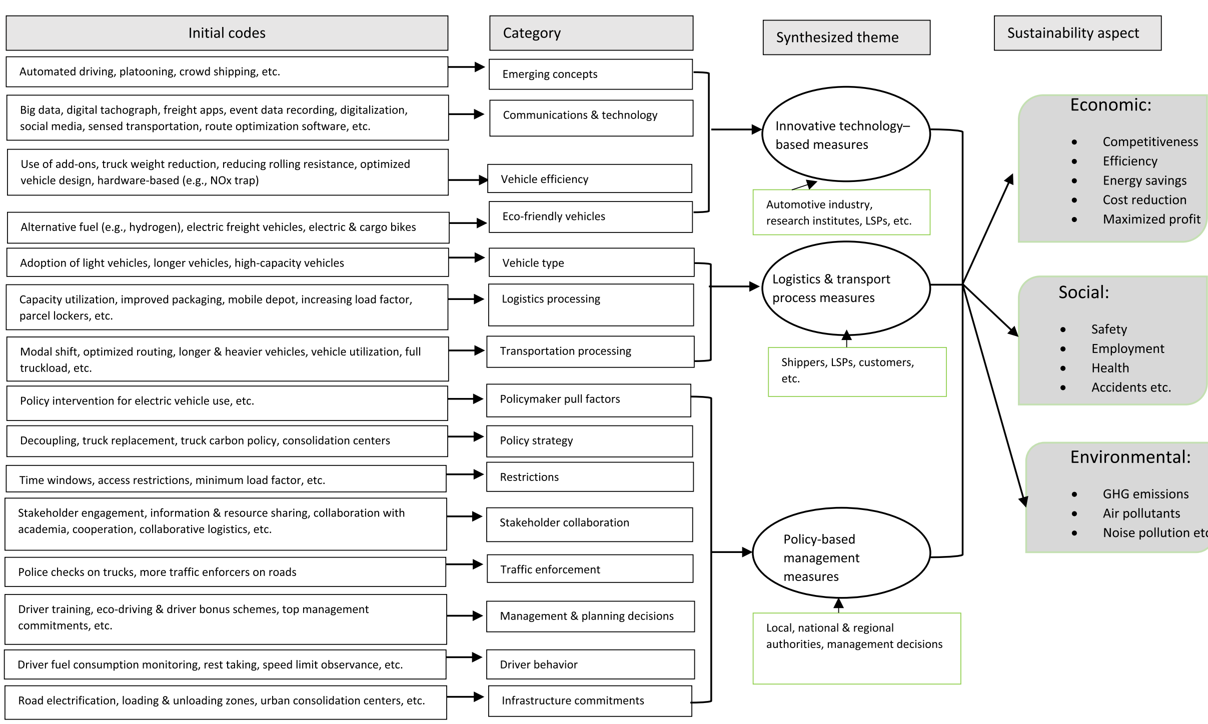

Fig. 2. The data structure of the synthesized proposed framework for road freight transport sustainability (RFTS).

the research method used, the sustainability aspect focus, the first author's continent affiliation, the study findings, and suggested strategies for improvement. In the second step, the information gathered in the first step was used to generate initial codes. To become familiar with the data, it is important to take notes and reflect upon the content (Braun & Clarke, 2006; Fryer, 2022). The coding units used were words, phrases, and sentences (Mayring, 2014). The study identified and coded specific, and relevant intervention(s) suggested in the papers for improving RFTS. NVivo version 1.7.1 (1534) software program was used to upload, code, and analyze the data. The initial coding resulted in 101 codes. In the third step, categories were developed based on the initial codes by first identifying codes that refer to the same, or similar, concepts and then consolidating these codes into new and broader categories (Fryer, 2022). This process resulted in the identification of 15 categories.

Finally, synthesized themes were developed based on the existing categories (Braun & Clarke, 2006) as each theme consisted of a minimum of two categories (Lockwood et al., 2015). In *meta*-aggregation, the overarching description of a group of categories—that is, the synthesized findings—can function as indicatory statements upon which policy and practice recommendations are based (Lockwood et al., 2015).

Based on the thematic analysis (Braun & Clarke, 2006), and a series of rounds of theme development, the 15 categories identified in step three were synthesized into three themes: (a) innovative technology–based measures, (b) policy-based management measures, and (c) logistics and transport process measures to improve the social, economic, and environmental sustainability of RFT.

Fig. 2 provides a diagrammatical representation from data through to synthesis in *meta*-aggregation (Lockwood et al., 2015), leading to the proposed framework. It is worth noting that the rolling out of these synthesized measures effectively will address many of, if not all, the fundamental road-based freight transportation sustainability issues of concern under the respective aspects i.e., economic, social, and environmental.

Note. LSP = logistics service provider, GHG = greenhouse gas.

Findings

The findings of a systematic literature review can be presented as both descriptive and thematic findings (Durach et al., 2017; Tranfield et al., 2003).

Descriptive presentation of findings

The descriptive presentation of the included articles focused on publication frequency, the publishing journals, the aspects of RFTS, the geographical regions that do the most research on RFTS, and the research methods used.

Number of publications per year

The study found yearly fluctuations of published articles with the years 2018, 2020, and 2022 having many published articles accounting for 13, 12, and 11. The lowest number of published articles was in the years 2021 with 2 articles, and in 2016 and 2019 having 4 articles each. This is shown in Fig. 3.

Publication channels

The 75 articles were published in 41 journals. 28 journals published only one article each, whereas 13 journals published two or more articles. Most articles were published in *Sustainability* (9) and *Transportation Research Part D: Transport and Environment* (8). The 13 journals that published two or more articles account for almost 63 % of the articles. This is shown in Fig. 4.

Sustainability focus of articles

Eleven articles (15 %) focused on all three aspects of sustainability. The most frequent individual-focused sustainability perspective was environmental sustainability, with 31 articles (41 %); social sustainability with 6 articles (8 %), and economic sustainability with 5 articles (7 %). Overall, the environmental aspect is the dominant focus in the included articles. The articles sustainability focus is shown in Fig. 5.

Publication by continent

The geographical distribution of the authors, particularly the first author's affiliation was not evenly distributed. In about two-thirds of the articles, the first author was affiliated with an institution in Europe. As Europe accounts for the highest number of articles (51), in terms of country affiliation Sweden has the majority of articles (11), followed by the UK (10), Italy (7), Spain (5), Finland (4). Norway, Greece, Portugal, and Belgium had (2) each as well as Netherlands, Germany, Lithuania, Ireland, Croatia, and Poland with a paper (1) each. This may be due to European policymakers' commitment to providing research funding to reduce the negative externalities of RFT. Asia had 11 papers (15 %) and North America with six papers (8 %). Researchers from Africa, Oceania, and South America had very few studies on this topic. This is shown in Fig. 6.

Publication by research method

The included articles featured quantitative methods (e.g., surveys, mathematical models, optimization, simulations), qualitative methods (e.g., case studies, interviews), and mixed methods - studies that apply two or more methods, e.g. Leach et al. (2013). Each method employed is shown in Fig. 7.

Thematic content analysis

The thematic content analysis involved systematically sorting the content of the included articles by identifying findings, relationships, and emerging themes from the data (Evers et al., 2023). This analysis takes the form of coding and then grouping similar codes into categories to identify emerging themes for synthesis (Evers et al., 2023). Subsequently, the framework in Fig. 2 was generated, where three broad categories of means for improving RFTS were formulated: (a) innovative technology–based measures, (b) policy-based management measures, and (c) logistics and transport process measures. The relevant key stakeholders in the promotion of the themes were put under respective synthesized themes in Fig. 2. Strategies are not mutually exclusive, as one strand of strategy can benefit two or more aspects, for example, truck platooning.

It is worth noting that previous literature has done a similar classification of themes. Patella et al. (2020) literature review on the adoption of green vehicles in last-mile logistics found three main categories, namely: optimization and scheduling, policy, and sustainability. Tob-Ogu et al., 1923 conducted a systematic review of sustainability intervention mechanisms for managing road freight transport externalities between 2001 and 2018. Based on the content and thematic analysis, the study categorized six themes for sustainability intervention mechanisms, namely: (1) decoupling - splitting economic growth from freight transportation, (2) Information and Communication Technology(ICT) -

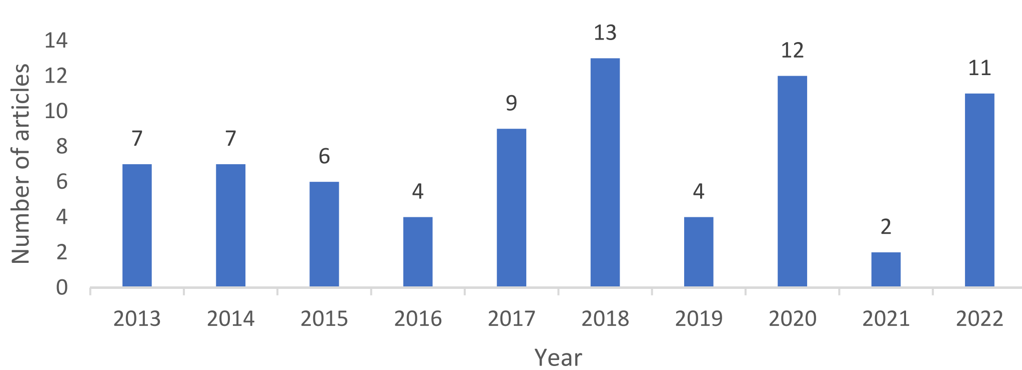

Fig. 3. Number of articles published each year.

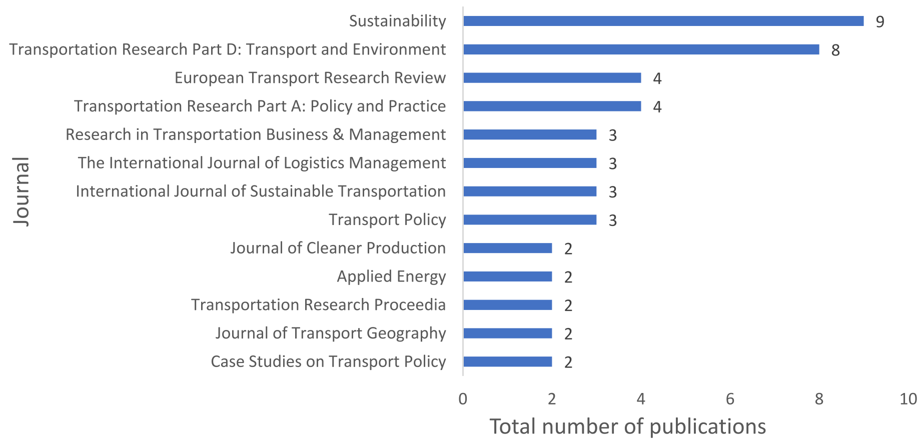

Fig. 4. Journals that published two or more articles.

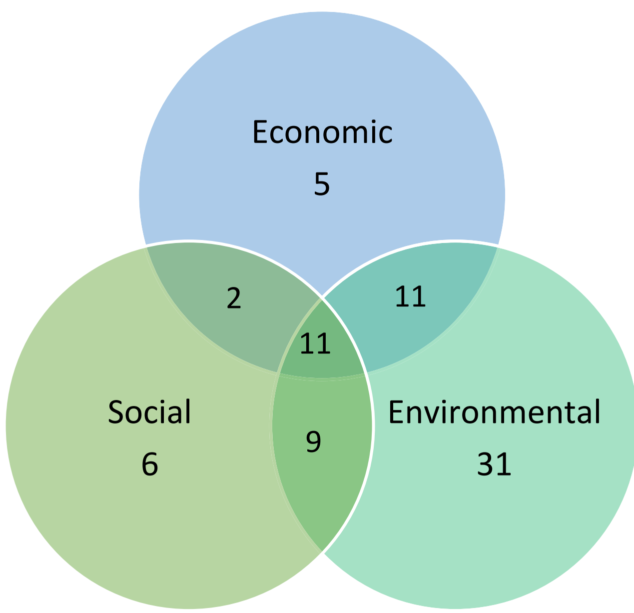

Fig. 5. Article content distribution based on sustainability aspect focus.

encapsulating information systems, big data, etc., (3) modality - captures means and modes of freight transportation, (4) operations - a combination of equipment and process design initiatives, (5) policy - mechanisms that are state-driven, and (6) other (e.g., land use, urban consolidation centers). The difference with this present study categorization is how broad these measures extend, for example, policy and decoupling could be under one such as policy-based management measures, as well as modality and operations under logistics and transport process measures. All in all, one could observe that policy, logistics, and transportation-based measures are paramount for improving road freight transportation.

The themes identified and their relationship to sustainable RFT are shown in Fig. 8.

Discussion

This section has two parts. The first part presents measures that the study identified to improve RFTS. In the second part, the focus shifts toward what stakeholders can do to improve RFTS.

Measures that can improve RFTS

Innovative technology-based measures

A significant contribution to making RFT more sustainable requires the deployment and adoption of new and innovative technologies. These technologies include information and communication technology (ICT) that allows for digitizing freight transport; big data; improvements in vehicle design, platooning, and autonomous driving; and eco-friendly vehicles.

ICT in RFT includes information systems, telecommunication and information technologies, software applications, middleware, and audiovisual applications to support communication, conduct remote monitoring, and improve accessibility to enhance the management and efficiency of RFT (Li & Yu, 2017; Wang et al., 2015). Moreover, innovative technologies such as intelligent transportation systems (ITS), the

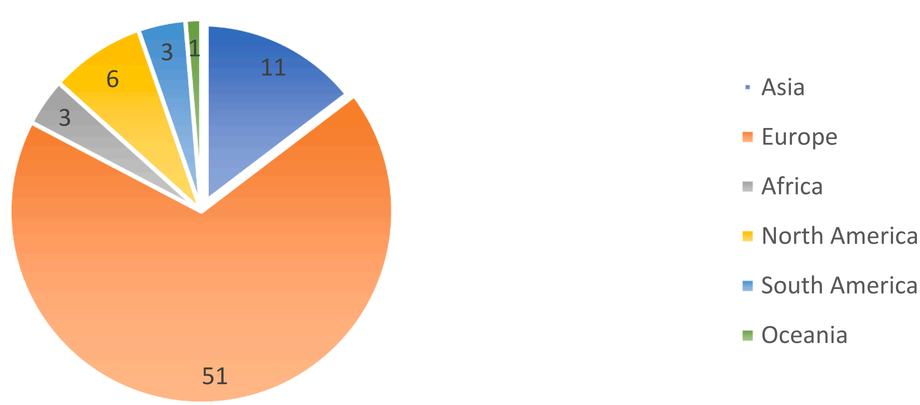

Fig. 6. Distribution of articles by continent.

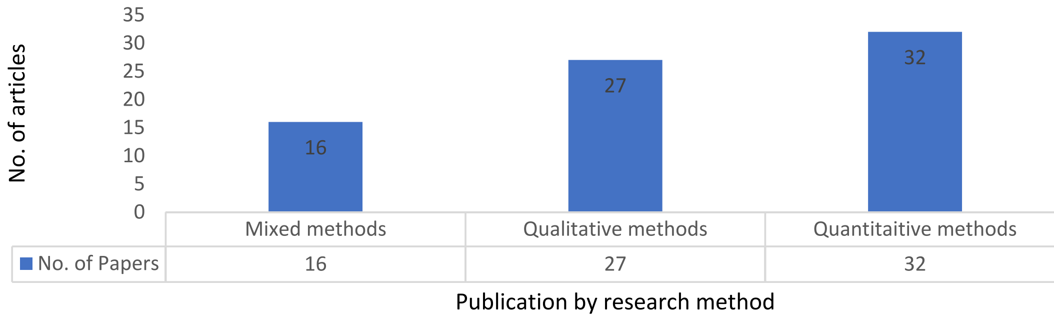

Fig. 7. Publication of articles by research method.

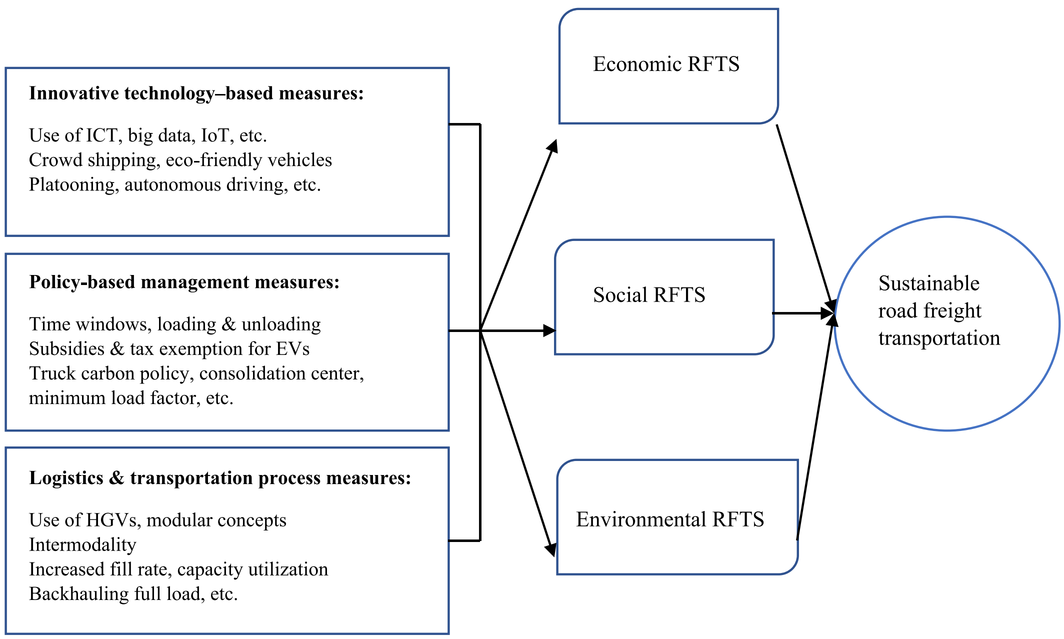

Fig. 8. Three themes affecting road freight transport sustainability (RFTS). *Note.* ICT = information and communication technologies, IoT = internet of things, EV = electric vehicle, HGV = heavy goods vehicle.

Internet of Things (IoT), big data, and artificial intelligence (AI) can be used to operationalize transportation systems on an integrated platform (Taniguchia et al., 2020). According to Wang et al. (2015), ICT can be applied on four levels in road transport with potential CO_2 emissions, namely at the (a) vehicle and load, (b) company, (c) supply chain, and (d) network levels. The authors excluded infrastructure-related technologies such as road pricing systems, congestion-charge management systems, and traffic information management systems, as they are designed for both passenger and freight transport.

On the vehicle and load levels, ICT might be utilized in digital tachographs (for digital data storage on driver and vehicle, e.g., driver smart card for recording driver activity) and telematics, including on-board computers, satellite receivers/GPS units, and communication to track vehicle movement, fuel consumption, and driver communication. The monitoring of vehicles could result in improved efficiency and safety (Pereira de Oliveira et al., 2020), and the real-time monitoring of vehicles facilitates resource pooling and capacity sharing (Mehmood et al., 2017). On the company level, ICT can be used in the deployment of enterprise systems with applications in transportation management needed for planning and scheduling, such as route planning, execution, and monitoring involving driver communication and real-time or retrospective tracking. On the supply chain level, ICT applications relate to customer relationship management, supply relationship management, and supply chain management systems. Finally, on the network level, ICT can be used to involve multiple actors via applications that use open electronic logistics marketplaces, especially for spot trading of transportation services between shippers and carriers. This is beneficial for backhauling. These marketplaces target long-term logistics services and execution in transport collaboration between shippers or carriers.

The significance of the role of ICT is seen in route optimization (Busho & Alemayehu, 2020; Vázquez-Noguerol et al., 2018; Wang et al., 2015), traffic management (Chatti, 2020; Li & Yu, 2017; Russo & Comi, 2016), backhauling (vehicles returning with load), and logistical efficiencies (Colicchia et al., 2013; Li & Yu, 2017; Wang et al., 2015). ICT and ITS also assist in data collection and analysis for decision-making in freight transport systems (Taniguchia et al., 2020). The digitization of freight transportation, including automation, digitized information flow, and artificial intelligence, is considered critical for green logistics, cost reductions, improving efficiency and service quality, and, as such, the development of competitive advantages for the companies that adopt it (Jarašūnienė et al., 2022; Pernestål et al., 2020). However, digitalization technologies favor large companies over small companies due to their financial capacity and the servicing of large volumes of freight (Jarašūnienė et al., 2022).

One of the essential components of the ICT infrastructure is IoT which promotes environmental sustainability (Bibri, 2018). The kind of connectivity attained by the IoT involves common objects such as people, roads, vehicles, goods etc., (Bibri, 2018). The IoT aims to *facilitate* *interactions between people, data, and goods to be transported, optimizing the exchange of information and the physical flow of goods* (Lagorio et al., 2020,p.9). IoT provides some level of flexibility and remoteness of work. Work could be done anywhere and anytime which makes people comfortable with their job schedule(s). As such the level of stress one experiences in traffic to and from work etc., would be avoided. This will enhance workers' health and improve quality of life, satisfaction, efficiency, and motivation to take up employment opportunities knowing the advantages of IoT-enabled tools and applications. Related to these is the reduction of travel and maintenance costs that could be incurred. Furthermore, IoT-using sensor systems help in traceability and monitoring during freight transportation. As a result, communication could be exchanged among people to improve safety, particularly when data is shared (possibly averting accident risks and congestions), aiding efficient distribution for economic and environmental benefits(e.g., reduced per unit cost, reduced fuel consumption, low greenhouse emissions).

Big data can generate business value through its operational and strategic capacity (Fosso Wamba et al., 2015). For actors involved in RFT to reap the benefits of big data, it needs to be robust, accessible, and interpretable (Mehmood et al., 2017). The automotive industry constantly aims to improve vehicle efficiency. This can be achieved through improved aerodynamics, reduced rolling resistance for tires, the use of new materials and designs to achieve weight reductions, new engine technologies (e.g., electric engines), and engine control that contribute to fuel savings and reduce CO_2 emissions (Jovanovic et al., 2020; Mulholland et al., 2018; Thijssen et al., 2014). The potential of new technology to improve the sustainability of RFT is evident from selective catalytic reduction technology that can mitigate NO_X emissions by as much as 75 %–90 % (Opatola et al., 2016).

Truck platooning—that is, trucks following each other closely and other form of vehicle-to-vehicle technologies —reduces air drag and fuel consumption (Bhoopalam et al., 2018) and can improve all aspects of RFT (Alam et al., 2015). First, when it comes to environmental sustainability, lower fuel consumption leads to reduced emissions such as CO_2 and particle matter. An increase in GHG emissions affects people negatively giving grounds for death and diseases as well as loss of productivity(Mayo et al., 2022). Alam et al. (2015), for example, observed that vehicles in second and third positions in platooning driving at 80 km/h 25 m behind the leading vehicle experience an average reduction in fuel consumption of 4 %–7% due to reduced aerodynamic drag. Second, when it comes to social sustainability, platooning can improve traffic safety (Alam et al., 2015) through the avoidance of human error, reduced driver fatigue, and allowing enough road space to avoid traffic congestion. Third, platooning contributes to fuel efficiency resulting from overall air drag reduction, which is key to economic sustainability (Alam et al., 2015). Moreover, according to Seidenova et al. (2022), total cost reductions of up to 30 % are feasible if the driver can be removed from the truck. However, the acceptance of both truck drivers and other road users is required for platooning to succeed (Paddeu & Denby, 2021).

Notwithstanding the potential benefits of platooning, it could result in people losing their jobs as well as being paid lower for less work done as the technology advances where not all trucks may need drivers on board. Platooning, in its purest form, requires the use of systems for autonomous driving, and such systems have been found to have positive safety implications compared to vehicles with human drivers (Ghandriz et al., 2020), and drivers experience less stress, which is also good for their health.

The adoption of green vehicles such as battery electric vehicles and electric cargo bicycles is highly commendable for freight transport (de Mello Bandeira et al., 2019). These vehicles require less maintenance and have lower operating costs, thus improving the company's long-term profitability. Additionally, greater demand for these vehicles leads to job creation in many developing countries. The public also perceives electric cargo bikes as less intimidating and safer, with minimal driver fatigue regardless of concerns about the carrying capacity (Melo & Baptista, 2017).

In the transportation sector, autonomous driving systems (ADSs) are seen as a transformation that provides the opportunity to enhance RFTS through productivity, logistics planning, and energy consumption (Ghandriz et al., 2020). Although the competitiveness of battery electric heavy vehicles (BEHVs) could be hampered by road hilliness, a reduction of up to 20 % of the total cost of ownership could be attained with BEHVs that have ADS and optimized electric propulsion systems and infrastructures (Ghandriz et al., 2020). The authors showed that a cost reduction of 27 %–46 % is attainable with ADS BEHVs, against 11 %–41 % for conventional heavy vehicles. The initial implementation of ADS in freight transport yielded a significant driver cost reduction (Ghandriz et al., 2020). In present times, related to social sustainability ADS needs a comprehensive overview.

Logistics and transport efficiency-based measures

The specific measures under this category include vehicle type used for freight transportation, logistics, transportation processing, etc., specifically transportation planning (Tacken et al., 2014). A typical example of transportation planning is the consolidation of goods (Arvidsson et al., 2013; Colicchia et al., 2013; Pålsson & Johansson, 2014). Such consolidation improves the load factor (Liljestrand, 2016; Makan & Heyns, 2018; Santén, 2017). Increasing load factor and efficiency depends on how well internal resources are utilized (Abbasi & Nilsson, 2016). Effective planning can also reduce empty running (Arvidsson et al., 2013; Wehner, 2018) and lead to the efficient management of reverse flow (Colicchia et al., 2013; Pålsson & Johansson, 2014) and an ordering system to avoid rush hour deliveries (Santén, 2017; Wehner, 2018). The vehicle type, mainly its size, and propulsion energy, must be considered in terms of the distance covered (city vs. long haul) and the quantity of freight to be transported. Therefore, more use of vehicles with high loading capacity is required for long-distance transportation (Liljestrand, 2016).

The willingness of transportation companies to use modular vehicles is crucial. Seidenova et al. (2022) noted that German companies showed reluctance after the German field trial and reported non-adoption by the European Commission of the cross-border use of modular vehicle combinations. The modal shift was chiefly highlighted for long-haul transportation (Chen et al., 2020; Sureeyatanapas et al., 2018). Intermodality, being the running concept, is considered appropriate for long-distance freight transport of large volumes (Liljestrand, 2016; Regmi & Hanaoka, 2015; Sureeyatanapas et al., 2018) to control transport distance covered by road that causes CO_2 emissions and noise pollution (Pålsson & Johansson, 2014).

Intermodal transport reduces climate impact from the perspective of shippers by 27 %–31 % in road to rail and 27 %–53 % in road to sea transportation (Liljestrand, 2016). Chen et al. (2020) examined the effects of the modal shift on energy consumption and carbon emission reduction in China. They measured four scenarios of moving 10 %, 20 %, and 30 % of road freight to rail against "do nothing," with 2015 as the base year and 2025 as the target year. For a 30 % shift to rail, energy consumption and carbon emissions, measured in million tons of oil equivalent, decreased by 27 % and approximately 17 %, respectively, compared to "do nothing." Regmi and Hanaoka (2015) showed through the modal shift that CO_2 emissions may decrease by 30 % if 43 % of freight shipping is moved from the road to the dedicated rail freight corridor. The motivation for the modal shift also depends on customer requirements (e.g., reliability, speed, flexibility) and wishes (Tacken et al., 2014).

Synchromodal transportation is closely related to intermodal transportation and can enhance freight transportation sustainability. Synchromodal transportation as an extension of intermodal transportation incorporates real-time rerouting of loading units for a network to cater to emerging disturbances and operation or customer requirements (Ambra et al., 2019,p.1607). This implies that modal choice decisions and routing are not determined in advance but when real-time developments emerge. Thus, the synchro modal concept has an advantage over intermodal transportation for better performance due to its flexibility, reliability, and other modal choice criteria (Ambra et al., 2019, p.1607).

Vehicle propulsion using non-fossil fuels is ultimately the answer. Many studies acknowledged the importance of switching to alternative fuels such as hydrogen, biofuel, and biodiesel (Arvidsson et al., 2013; Jovanovic et al., 2020; Pålsson & Johansson, 2014; Vázquez-Noguerol et al., 2018). However, alternative fuels are not widely used among companies transporting freight on roads (Colicchia et al., 2013; Jovanovic et al., 2020). In Germany and Sweden, the operational success of doing so has been limited (Pålsson & Johansson, 2014).

Logistics processing activities should consider improved packaging and load carrier design for weight and volume efficiency (Colicchia et al., 2013; Santén, 2017; Vázquez-Noguerol et al., 2018). One study found that the use of mobile depots in inner cities and the subsequent use of motorized tricycles for deliveries culminated in reduced greenhouse gas (GHG) emissions and pollutants (Marujo et al., 2018). Cities with higher customer density could resort to microhubs and crowd shipping (Ballare & Lin, 2020). The use of urban consolidation centers reduces travel distances and GHG emissions and improves local air quality (Paddeu, 2017).

Nicolaides et al. (2018) explored how electrifying RFT can be used to improve environmental sustainability in the United Kingdom. Despite the associated costs of electrification, they concluded that by 2040, CO_2 emissions could be reduced by 93 % by using electric freight vehicles.

Policy-based management measures

This theme encompasses policymakers' pull factors, policy strategies, restrictions, stakeholder collaboration, driver behavior, management and planning decisions, traffic enforcement, and so on. Policymakers and management stimulate behavior at the local, regional, national, and organizational levels, particularly targeting driver behavior, ensuring efficiency, and stakeholder collaboration (direct and indirect). Direct stakeholder collaboration refers to collaboration between the main stakeholders in freight transportation operations such as logistics service providers (LSPs), carriers, shippers, and the automotive industry. Indirect stakeholder collaboration refers to the transfer of knowledge that may come from, for example, academic and research institutions to assist in research outcomes to promote RFTS.

A growing body of literature proposed specific strategies such as deliveries during off-peak hours or at night (Russo & Comi, 2016), introducing congestion charges (Stelling, 2014), well-managed urban consolidation centers (Lin et al., 2014; Paddeu, 2017), and decoupling - referring *to undo the traditional link between economic growth and road transport activity* (Alises & Vassallo, 2015,p.142; Liimatainen & Pöllänen, 2013). Policies could also be based on the introduction of incentives. Arvidsson et al. (2013) highlighted, for example, how Copenhagen introduced a licensing system for LSPs that meet 60 % of the load factor to access their preferred loading and unloading areas, which was welcomed by LSPs. Similarly, Gothenburg introduced a system where a load factor of 60 % or deliveries to over 50 recipients give access to particular loading zones or bus lines (Arvidsson et al., 2013). These two policy schemes incentivized higher load factors and contributed to fewer trucks on the roads.

The European Union, in July 2021, introduced the Fit for 55 regulation, an ambitious goal of reducing GHG emissions in the European Union by 55 % by 2030 (Solakivi et al., 2022). Such policy target measures are expected to incentivize both LSPs and the automotive industry to reduce GHG emissions and speed up the development of vehicles to meet these expectations. Similar measures could be strengthened and replicated in other regional blocks if we intend to achieve climate neutrality by 2050.

Other studies identified regular eco-driving training for fleet drivers, use of automated engine shutdown, monitoring tire inflation, and maintaining the technical standards of vehicles (Abbasi & Nilsson, 2016; Makan & Heyns, 2018; Paddeu & Denby, 2021) as effective means to improve energy efficiency. Eco-driving bonus schemes can improve the energy efficiency of RFT (Liimatainen et al., 2014). These strategies can be implemented effectively if employees embrace the urgency required to be sustainable. Consequently, Abbasi and Nilsson (2016) highlighted education for staff about ethical and environmental operations, such as the Go-Green and Go-Teach programs initiated by DHL.

Specific regulations or policy interventions can take the form of traffic and maximum payload regulations and vehicle utilization rates (Stelling, 2014). Splitting the payload may be helpful because larger vehicles are unsuitable for some operations, such as city delivery (Liimatainen et al., 2014). Mayo et al. (2022) found that increasing the number of traffic enforcers, such as police and other law enforcers responsible for traffic management, and dynamic vehicle operation restrictions i.e., taking the form of limiting vehicle usage, achieved a significant reduction in road deaths. Elvik et al. (2022) investigated how police checks on heavy goods vehicles (HGVs) influence accident rates in Norway and found a negative relationship between police checks and the number of accidents involving HGVs. As more drivers were subjected to checks, fewer accidents occurred.

The incentives component of the regulations and policies comprises purchase subsidies and tax exemptions for electric vehicles (EVs) used for freight transport. These policies were found to increase EV sales (Mirhedayatian & Yan, 2018). Seamless traffic flow could be regulated through traffic lights and speed limits (Liimatainen et al., 2014). Furthermore, both shippers and LSPs could embark upon responsible contracting including the fulfillment of social and environmental requirements (Abbasi & Nilsson, 2016).

Ways stakeholders can contribute to improving RFTS

The stakeholders in freight-related decisions have been viewed from different perspectives (Muñuzuri et al., 2005; Ogden, 1992; Stathopolous et al., 2012), and the main stakeholders considered in this study are shippers, hauliers, LSPs, customers, and policymakers.

Concerted collaboration and cooperation

For this study, "collaboration" and "cooperation" are used interchangeably. *Cooperation* refers to compromising to work together since some may be worse off (lower benefits or higher costs, or both, at least within the short term) ((Miller, 2013,p.297). Promoting and engaging in collaborative logistics is critical (Anagnostopoulou et al., 2019; Ouhader & El Kyal, 2017; Vázquez-Noguerol et al., 2018). However, Vázquez-Noguerol et al. (2018) observed that collaboration among competing companies has not received the necessary attention. Information remains the lifeblood of a cooperative transportation system, and sharing transportation resources can curb wasted capacity in the transportation system (Miller, 2013). The lack of information about available loads accounts for empty running and lower fill rates (Liimatainen et al., 2014). To address this problem, it is recommended that hauliers establish a network to enhance knowledge sharing on backloading (Liimatainen et al., 2014). Again, the level of knowledge could be improved when web-based tendering for freight transportation services occurs on a wide scale (Liimatainen et al., 2014).

More complex behavior such as collaboration requires shared credit and responsibility (Miller, 2013; Shirky, 2008). The extent of willingness to collaborate and collaboration between shippers and LSPs are critical (Abbasi & Nilsson, 2016). Therefore, cooperating in transport-related activities requires an actor to make some level of sacrifice for the greater good relative to information sharing and resources. In the long term, it leads to less congestion, emissions, and resource consumption and improved communities, mainly through information and resource sharing at a higher level of coordination (Miller, 2013). Collaboration offers an opportunity to achieve a reduction in per-unit product transportation costs (Ouhader & El Kyal, 2017).

It is equally important that LSPs collaborate with the automotive industry, such as in manufacturing specific freights required for their operations in an environmentally friendly manner (Abbasi & Nilsson, 2016). Furthermore, the need for increased collaboration with researchers and advisory councils connected with development and research has been greatly emphasized (Abbasi & Nilsson, 2016).

Stakeholder demands and pressure

The extent of stakeholders' demands for sustainable delivery could be re-examined. To unravel the impediments to LSPs' ability to be more environmentally friendly, Abbasi and Nilsson (2016) highlighted four main categories, including customer priorities where time and price are more important than sustainable solutions. This can affect the fill rate, with higher emissions when using fossil fuel. Therefore, customers must be willing to pay for sustainable delivery. Customers' demands and expectations, regulations, and political commitments are strong tools that can push firms to adopt electric freight vehicles (Melander et al., 2022).

Pöllänen et al. (2021) showed Finish hauliers' disinterest in improving environmental practices to work toward ambitious climate goals. This was attributed to a lack of pressure from shippers for hauliers to embark upon energy efficiency. This underscores the call for both pressure on and support for hauliers to engage in more environmentally friendly practices. Such momentum will motivate LSPs in particular to improve their operations and integrate a strategic vision of sustainability in their operations (Fulzele & Shankar, 2022). A study within the Scandinavian countries showed that sustainability plans are not well entrenched in the mission and vision statements of many LSPs (Abbasi & Nilsson, 2016). Through pressure, these LSPs' business models will stress green and environmental business operations.

Furthermore, there is a need to advance the discussion on mandatory corporate sustainability reporting among LSPs. Extending the Corporate Sustainability Reporting Directive to LSPs will mandate them to disclose their societal and environmental impacts. Their reporting could be authenticated through independent auditing. This will be an incentive to push for sustainable solutions to win contracts. The procurement of LSPs' services could prioritize fleet type, fuel used, and frequency of servicing, factors that all impact noise level and carbon and particulate matter emissions. The new EU sustainability reporting requirements are limited to only large companies within the European Union and non-EU companies with a turnover of over €150 million in Europe (European Parliament, 2022). Similar interventions could be extended to actors in RFT such as LSPs worldwide.

Furthermore, drivers' behavior affects fuel consumption and safety on the roads. It is incumbent on policymakers and more importantly, the management of hauliers to undertake awareness programs and mandatory eco-driving as a requirement for securing a driver's license. Fuel savings of 5 %–15 % could be attained from eco-driving training (Liimatainen et al., 2014).

Capital investment

An important role of the public sector is infrastructure development (Miller, 2013). The government can scale up infrastructure building that seeks to optimize freight transportation in the form of loading and unloading zones and dedicated lanes for freight vehicles (Russo & Comi, 2016). Dedicated freight corridors, or urban transportation subnetworks, should be promoted, as they improve road safety and curtail accidents (Rodrigues et al., 2015). Moreover, technology use could enhance the enforcement of traffic safety. Nevertheless, as Elvik et al. (2022) noted, enforcement by technology takes many years.

Within long-haul freight transportation, national policymakers could consider road electrification on a section of the road network for HGVs with a gross mass of 38.5–48.5 tons (35–44 tonnes). Such projects are costly, and the government must be prepared to meet these costs. Additionally, as intermodal transportation is being explored, it will unravel critical concerns that need improvement and that need to be adequately addressed by infrastructure owners and managers. The extent of the patronage of railroads depends on quality, availability, reliability, and infrastructure investment. Public–private partnerships could be explored for infrastructure development in railways when the government experiences funding challenges.

The cost disparity of the size of road hauliers is a critical concern to investigate. As observed by Pöllänen et al. (2021), road hauliers size informs decisions in setting environmental reduction targets, as bigger companies have had targets set based on their resource capacity. This cannot be said of small hauliers, possibly because of the associated costs. Favorable government policies could be geared toward small hauliers' sustainability undertakings. It has been recognized that it is expensive to change and adapt, especially when it requires a new environmentally friendly fleet, adjustment to sustainability guidelines, internal synchronization, staff recruitment, and staff training (Abbasi & Nilsson, 2016). Sometimes, the cost involved seems prohibitive and can demotivate willing actors in pursuit of sustainable solutions.

Strengthening of existing laws

The business environment is ever-changing, and one needs to be well-informed and able to adjust to the present challenges. The European Union has consistently been adopting more stringent emission standards. The proposed Euro 7 emissions standards, set to come into effect on July 1, 2027, include HGVs and are necessary to set more ambitious reductions in air pollution and keep vehicles clean for the greater part of their use (European Commission, 2022). It is expected that by 2035, Euro 7 will cut NOx emissions by 56 %, toward the European Green Deal (European Commission, 2022). Vehicle manufacturers will have to lower emissions more than required by the previous Euro VI standards. Although this comes at a cost (e.g., the expected additional purchase cost for HGVs is approximately €2,700), the standards have significant environmental benefits against the cost to manufacturers, consumers, and authorities by a ratio of more than 5:1 (European Commission, 2022).

A recent European Commission proposal on the emission trading system, the world's largest carbon market, for an extension to cover new sectors, particularly emissions from fuels used in road transport, is welcome in the organization's efforts toward decarbonization (European Commision, 2021). This needs to be replicated in other jurisdictions. The discussion on the inclusion of the transportation sector has stagnated for far too long, since 2012, when air transportation was added (Stelling, 2014). With such interventions, LSPs will be left with no option but to comply and hence will be inspired to purchase cleaner freight vehicles if they intend to remain in business.

Local authorities must demonstrate their preparedness to push for zero-emission vehicles for freight transportation. Vehicle manufacturers should have clearly defined timelines for sales of electric freight transport vehicles and the ban on fossil fuel–propulsion vehicles. Governments could institute legislation for LSPs to be net zero within a certain timeframe. Increasing adoption requires the provision of funds, commitments to install electric charging points at lower cost by the state authorities, and investment in research and development in energy-efficient propulsions.

California's executive order for zero emissions from medium- and heavy-duty vehicles by 2045 and drayage trucks by 2035 for all operations remains a driver for more zero-emissions truck production (Executive Department State of California, 2020). There is a need to ensure bottom-up policy measure implementation to forestall stiff opposition (Ballantyne et al., 2013), as local authorities normally fail in this aspect (Russo & Comi, 2011). Internal sanctions for noncompliant drivers should be reviewed to deter potential lawbreakers.

Balancing disparate objectives among stakeholders remains to some extent problematic. Sometimes conflicting interests thwart the selection of appropriate policy measures (Rai et al., 2017). This is a result of different stakeholders' objectives (Taniguchia et al., 2020). Hence, considering stakeholders' conflicting norms, expectations, and interests regarding sustainability enhancement targets, stakeholders should not assume an entrenched position to thwart well-meaning strategies to achieve sustainability goals and interventions.

Concluding remarks

The study examined how RFTS could be enhanced through a *meta*-aggregation approach involving 75 articles. All studies acknowledged that cost savings, societal benefits, air and noise pollution reduction, and GHG emission reduction remain the central concerns of improving RFTS. However, among the three, the focus on the environment was greater than that on social and economic aspects.

Three themes were identified under which RFTS can be addressed: (a) innovative technology–based measures, (b) logistics and transport process measures, and (c) policy-based management measures. It was revealed that the successful attainment of RFTS depends on the cooperative nature of both direct and indirect actors, strengthening of existing laws, capital investment, and stakeholder demands and pressure. One intriguing observation relates to the swift transition from the business-as-usual traditional logistics and transport operations to more regulations and policies and an extensive shift toward innovative technologies. It was evident from the literature that Europe and other developed countries have a clear path to address the workability of the measures identified. However, the same cannot be said about developing countries. Therefore, global attainment of all the benefits of sustainable freight transportation will come to nothing if strategies are not designed to bring everyone on board.

Meta-aggregative reviews aim to inform practice based on the original data and findings (Lockwood et al., 2015). Thus, this study may be one of the few studies that will guide managers and policymakers in the quest for RFTS and integrating sustainability into operations using up-to-date remedial tools and actions that can be implemented for overall sustainability. Another implication is that RFTS is impossible if stakeholders fail to underscore the need for strengthened collaboration among both direct and indirect actors. These actors should see the need for collaboration to ensure the overall sustainability of the logistics system.

The study proposes four future research directions. First, decoupling strategies and road electrification have been explored exclusively in Europe. Therefore, further studies should be conducted on its wide adoption among carriers, using surveys or qualitative interviews, particularly in developing countries with ostensibly limited support interventions for such vehicles. Second, studies are rarely conducted on collaboration among shippers for enhanced RFTS. Recognizing the important role of collaboration, cooperation, and competition, further studies must be conducted to assess the impact of these concepts considering the company's size.

Third, the extant literature has clearly shown the depth of studies within Europe about sustainable road freight measures with clear systematic interventions and policies, irrespective of the distance covered. The same cannot be said about emerging economies and developing countries. Therefore, more empirical studies are needed in these areas so that the common purpose of attaining SDG targets by 2030 and carbon neutrality by 2050 can be achieved collectively. Fourth, the social aspect of RFTS has not received the needed attention when it comes to perceptions of accident occurrence, and its possible avoidance. Limited focus has been on rural road networks used by HGVs, and with a high perception of risk of accidents when meeting such vehicles. This offers an opportunity to delve into road travelers' behavioral aspects through methods such as the stated preference to study willingness to pay to avoid road accidents involving HGVs. Lastly, further research is warranted to know the extent to which the employment of truck drivers will be impacted by the uptake of platooning.

This paper has limitations related to the retrieval of the relevant literature, as only the Scopus and Web of Science databases were used. The review of only peer-reviewed articles limits information retrieval, as relevant records from books, articles in other languages, reports, conference proceedings, and so forth were excluded. This allows for future improvement by expanding the material selection and search strings used in this study. Furthermore, the review did not benefit from the intercoder agreement, as one researcher was involved in the coding process.

Declaration of Competing Interest

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

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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