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ROLE OF GREEN LOGISTICS IN THE CONSTRUCTION OF SUSTAINABLE SUPPLY CHAINS

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ABSTRACT

The global supply chain has been growing strongly in recent years. This development brings many benefits to the economy, society, and human resources in each country but also causes a large number of concerns related to the environment since traditional logistics activities in the supply chain have been releasing a significant amount of emissions. For that reason, many solutions have been proposed to deal with these environmental pollution problems. Among these, three promising solutions are expected to completely solve environmental problems in every supply chain: (i) Application of blockchain in the supply chain, (ii) Use of renewable energy and alternative fuels, and (iii) Design of a closed supply chain. However, it seems to lack a comprehensive study of these solutions aiming to overcome the drawbacks of traditional logistics. Indeed, this work focuses on analyzing and evaluating the three above-mentioned solutions and the impacts of each solution on solving problems related to traditional logistics. More importantly, this work also identifies critical factors and challenges such as policies, laws, awareness, and risks that are found to be remarkable difficulties in the shifting progress of traditional logistics to green logistics. Finally, directions for developing and deploying green solutions to the logistics, supply chain, and shipping sectors toward decarbonization strategies and net-zero goals are discussed in detail.

Keywords: green logistics, supply chain, environmental pollution, sustainable development

INTRODUCTION

With the current trends towards globalisation, the supply chain is expanding to meet the increasing needs of society [1]. However, when the supply chain develops too quickly, it will have negative effects, the most obvious of which are problems with environmental pollution [2]. This forces businesses to pay attention to their environmental impacts and to find ways to address them [3][4]. a common aim of businesses and organisations operating in all sectors is to continuously improve their tools and operating methods to create sustainable development, without causing negative impacts on the environment, while still optimising their operating costs [5]. Of the latest solutions put forward, the green supply chain stands out as a viable and potential system for managing the supply chains of organisations and solving problems with environmental pollution [6][7]. In addition, trends towards globalisation have promoted the expansion of the supply chain, and an inevitable consequence of this is a significant increase in logistics activities [8]. This puts great pressure on the environment when solutions for limiting negative aspects are either incomplete or not yet operational [9]. According to data from 2016, emissions in transportation activities account for about one-quarter of total emissions;

more specifically, CO_2 emissions are currently about 8 Gt, representing an increase of about 71% compared to 1990 [10]. Among these, emissions from freight activities account for 42% of all transportation emissions [11][12][13], and are expected to reach 60% by 2050 [14]. Moreover, the remarkable decline of NOx, PM, and CO_2 emissions during lockdown due to the COVID-19 pandemic could be considered as believable proof of the significant contribution of transport activities to pollutant emissions [15][16][17]. Due to this reason, the International Energy Agency (IEA) has developed a Sustainable Development Scenario with a primary emphasis on lowering transportation-related CO_2 emissions. Direct CO_2 emissions from transport using fossil fuels are projected to decrease by over 90%, from 8.1 Gt in 2019 to 1 Gt in 2070, under the Sustainable Development Scenario [18]. Fig. 1 shows the pathway for achieving net-zero CO_2 pollution from energy around the world by 2070.

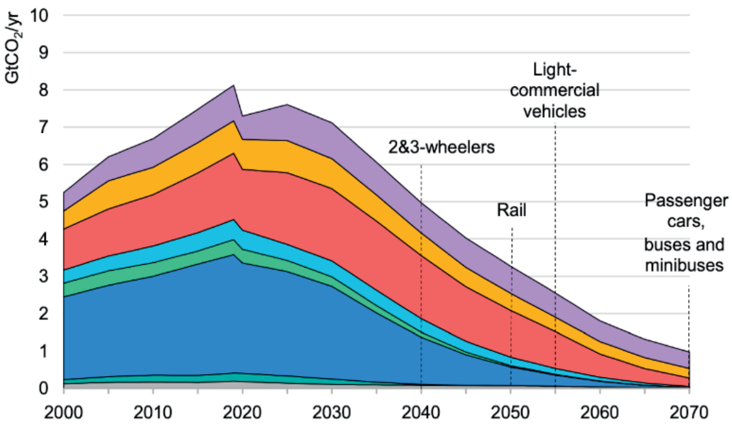

Fig. 1. Expected global CO_2 emissions from various modes of transport from 2000 to 2070, according to the Sustainable Development Scenario [18]

The requirements for the sustainable development of supply chains and transportation are of great interest to many countries and governments, although the outcomes achieved in each country have been very different [19]. It is, therefore, essential to consider the factors affecting sustainable development when comparing the efficiency of supply chain and logistics operations across countries with a view to moving towards green logistics (GL). Reducing harm to the environment is not only one of the great challenges in achieving a sustainable development strategy, but is also mandatory for organisations and businesses in all sectors, with logistics businesses being no exception [20]. The vital role of transport and logistics activities in the economy and social stability of countries cannot be denied, but they are also one of the main sources of environmental pollution [21] [22][23]. Environmental policies toward logistics businesses are becoming increasingly stringent; the two main reasons for this are the growing influence of the supply chain on the environment (in terms of higher congestion, lower safety, and greater environmental pollution) and the feasibility of building sustainable logistics systems. The demand for GL services is therefore rising by the day, leading to ever more initiatives being designed and deployed in this area. Supply chains are not only expanding in number, but also in terms of the complexity of supplier and enterprise networks, meaning that ways of managing these networks effectively are required [24]. Links between the implementation of green solutions in logistics management, economic growth, and the minimisation of negative impacts on the environment have been reported in studies by Aldakhil et al. [25] and Nguyen et al. [26]. In addition, the effective maintenance of green operations in logistics activities has been proven to help achieve both economic and environmental sustainability goals [27]. Karaman et al. [28] and Seroka-Stolka et al. [29] have reported that GL activities help the economic circle run more smoothly, thereby strongly boosting the overall economy of the country. Important practices include eco-friendly packaging design, and the adoption of green transport, storage, and processing practices. Fig. 2 shows the links between economic development, environmentally friendly operation, and sustainable supply chains [30].

In general, freight and logistics operations are the lifeblood of the supply chain, as they are concerned with the movement and storage of materials and products throughout the entire supply chain. Most supply chains today operate on the just-in-time model, which requires continuous and rapid movement of materials and products, management, and expansion of logistics activities, meaning that transportation becomes a vital element of the economy. The growth in road transport activities has therefore been considerably higher than for

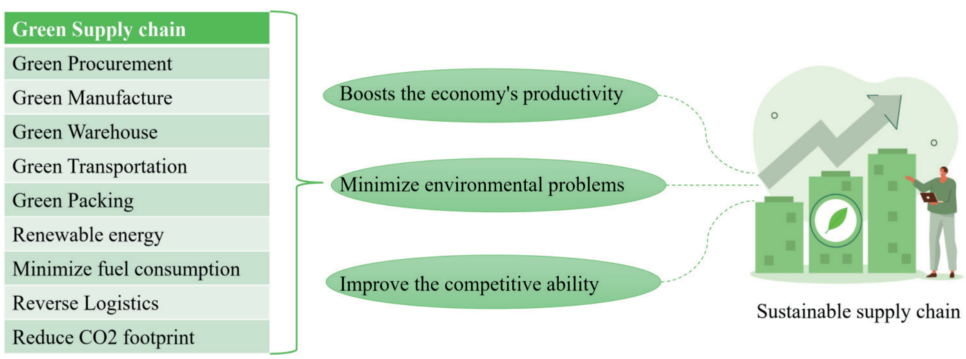

Fig. 2. Connections between sustainability issues, economic development, and the supply chain [30]

other transport activities [31]. However, in the absence of sustainable options for implementation, these processes cause negative environmental and social impacts. Indeed, Piecyk et al. [32] showed that freight transport accounted for a much higher share of emissions than other emissions related to transportation. The main reason for this was the abuse of just-in-time approaches to promote small but fast and continuous deliveries, mainly by trucks [33]. Most businesses still rely heavily on road transport, even though other means of transport such as air, waterways, and railways have significantly improved, primarily due to its low cost, high flexibility, and fast response times [34]. The consequence of this overuse of vehicles is that their CO_2 emissions are overwhelming compared to other causes; they account for 30–40% of the total emissions from the industry [35]. For all of these reasons, green transport strategies need to be implemented throughout the supply chain and logistics operations. In addition, it is necessary to continuously check and measure the operational efficiency, as this is important in determining the ability to implement and maintain a strategy as well as the success of the strategy; it therefore affects the economic aspects of the business, and requires a meaningful green transport strategy. a paradigm for environmentally friendly logistics, founded on the operational concepts of environmentally friendly growth and logistics, is presented below in Fig. 3 [36].

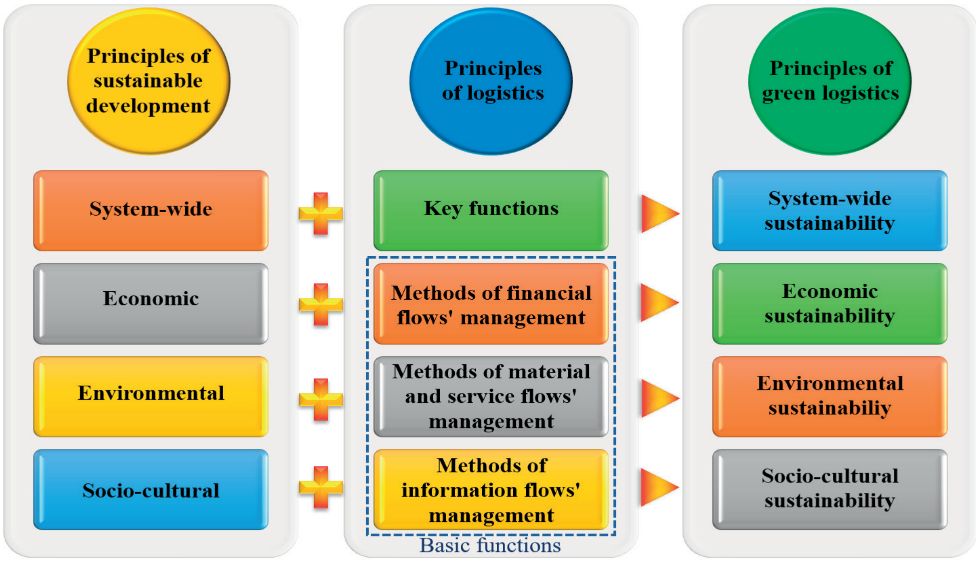

Fig. 3: Green logistics: a conceptual framework [36]

From Fig 3, it could be seen that benchmarks for measuring transport business success include factors relating to sustainable development, these factors are particularly important for the logistics field. However, there have been limits in understanding, developing, and deploying green logistics. Therefore, the main focus of this work is on highlighting the most important aspects of the role of GL in establishing a sustainable supply chain. The paper consists of five parts, in which Section 2 reviews the theoretical foundations of existing research, while Section 3 describes recent trends in the use of GL systems to build a sustainable supply chain. In addition, applications and future trends in GL in this section is also reviewed in this section. Section 4 discusses perspectives and future directions for GL in the construction of a sustainable supply chain. The final section presents the conclusions and key findings of this work.

THEORETICAL BACKGROUND

CONCEPTUAL BASIS OF GREEN LOGISTICS

Effective supply chain management is a leading factor in the sustainable development of a business. Over the past few decades, researchers, scientists, managers, and politicians around the world have strived to develop a general concept of sustainable development that can be combined with social and environmental goals without affecting economic success. Bajdor et al. [37] claim that the concept of sustainable development has changed the approaches and business strategies of modern companies, which aim to maintain and develop their economic and financial profits while also ensuring social order and minimising the negative impacts on the environment. With a view to adapting and optimising the transport policies of enterprises while still being able to protect resources and the environment, today's supply chain and logistics systems are oriented towards green transport [38][39][40][41][42]. Green transport is an important link in the logistics chain, and is commonly defined as a way of transporting supplies (raw materials and products) that minimises the negative impacts on the environment. Enterprises or organisations often consider integrating green transport into the supply chain, with the desire to maintain and improve the smooth operation of the system while still being able to meet the strict requirements of the law on environmental issues and the performance of suppliers and customers [43]. It is, therefore, necessary to evaluate and analyse the important factors affecting the development of an appropriate greening roadmap [44][45][46]. In particular, small and medium enterprises are less involved in (or even completely left out of) the trend towards globalisation, and find complicated policies more difficult to apply. Issues such as organisational management, corporate culture, and social attitudes to change present major barriers to the practice of sustainable development, not only in the field of logistics but also in the management of the whole business stalled [47][48][49].

The fact shows that GL is not only a scientific or economic concept but also the next stage in the development of enterprise logistics. Since most logistics concepts are very close to reality and dynamic, the ability to access and operate GL will provide a special competitive advantage to transport companies, thereby demonstrating the strategic vision of the business [50][51][52]. In addition to improving the economic and environmental aspects of businesses, GL also has positive effects on both the state and society. The key element of GL is to protect the environment by solving or reducing problems related to road traffic emissions. As reported, the composition and degree of toxicity of exhaust gas emissions caused by vehicles are determined based on the design of the engine, the quality and the composition of the used fuel, the fuel types, and the technical conditions of vehicles [50][53][54][55]. Due to this reason, a large number of advanced technologies relating to the use of additives or alternative fuels [56][57][58][59], the application of hybrid/electric vehicles [60][61][62][63], the improvement of the combustion process of engines [64][65][66][67], and the application of advanced injection technology and post-treatment technology for exhaust gas [68][69][70] have been considered as efficient solutions to reduce pollutant emissions from internal combustion engines-based vehicles that are used for logistics activities. The fact shows that in most businesses, logistics is one of the primary areas considered for improvement with the aim of reducing costs and optimising profits [71]. This term is not new, and is widely used in most business fields and in financial statements. However, in recent years, the concept of GL has gradually emerged to replace existing concepts, in which GL is defined as all efforts and measures undertaken to minimise the negative environmental impacts of logistics activities on the ecosystem. a large body of scientific literature has been published by researchers, indicating that GL has received special attention in recent years, and it has close relevance to the goal of sustainable development [72][73][74][75][76][77][78][79][80][81][82][83]. Fig. 4 illustrates the main targets of GL in practice.

It could be observed from Fig. 4 that there is a strong relationship between GL and sustainable development via activities such as green transportation, green storage, green packaging, green organisation, GL data collection and management, and waste management [85][86][87][88][89]. In a study by Karia and Asaari [90], it was stated that green packaging involves the use of economically sustainable materials, environmental and social responsibility, and processes such as recycling and reuse; green storage involves space optimisation and energy consumption reserves; and green transport involves using green vehicles and fuels, and contributing to sustainable development in areas such as economics, the environment and society. In order to maintain the consistency of economic, environmental and social aspects, planning is necessary in regard to the control, monitoring and evaluation of GL.

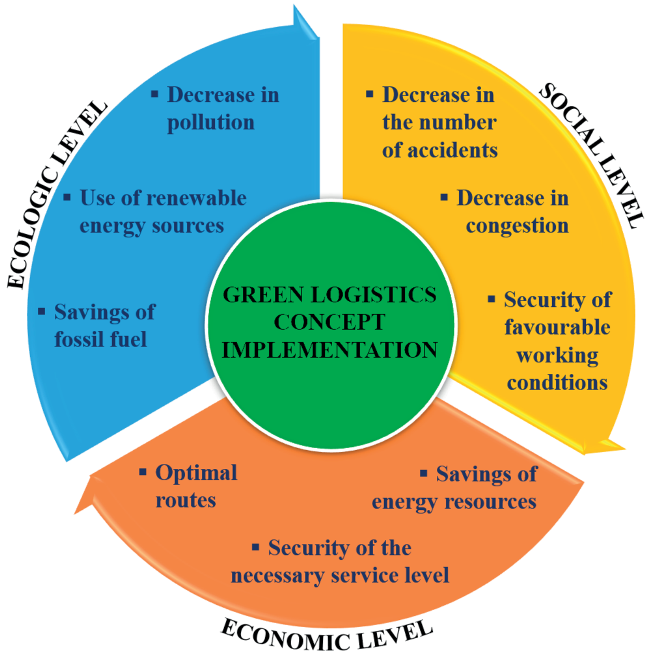

Fig. 4. Primary aims of green logistics in practice [84]

Thanks to advanced management, software and information systems, GL data collection and processing activities have not only been significantly improved, but the use of paper documents has also been minimised, which is a valuable part of the greening of management activities. Despite some differences between definitions, some common terms can be easily recognised [91], such as ‚supply chain environmental management' [92], ‚green purchasing and procurement' [93], ‚green logistics and environmental logistics' [94], and ‚sustainable supply network management' [95].

BENEFITS OF GREEN LOGISTICS

The increasing amounts of emissions from vehicles in the supply chain have attracted the attention of governments around the world. While most industrial firms are only interested in reducing logistics costs rather than being aware of environmental issues, there have been many studies, showing that reducing logistics costs in the right way can also reduce negative impacts on the environment. The concept of GL was born from this finding. The most pressing problems of environmental pollution, such as climate change, are consequences of global warming and the greenhouse effect [96]. Another problem is air pollution, which is mainly caused by CO_2 emitted during transportation by trucks and other types of transport [97]. Therefore, if an efficient distribution centre can be built, the amount of transportation needed will be reduced, leading to reductions in transportation costs and emissions to the environment. In contrast, a lack of systematic and effective organisation will cost businesses in terms of both money and time, and will also affect the living environment. Fig. 5 illustrates the environmental impacts of logistics operations such as the handling of materials and physical distribution flow management aiming to attain the GL goals.

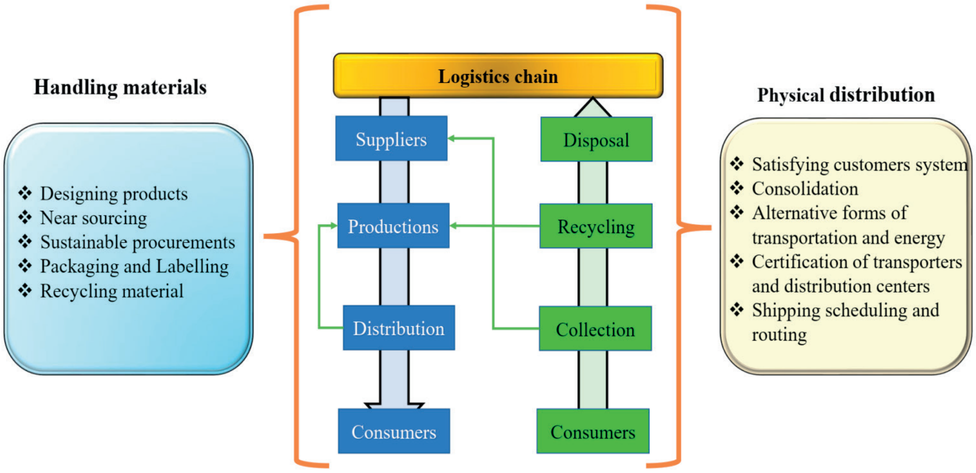

Fig. 5. Ecological impacts of the logistics chain [98]

There are many studies that have highlighted the benefits of GL activities from different perspectives. Khan [21], Richnak et al. [85], Maas et al. [99], Azevedo et al. [100], and Sureeyatanap et al. [86] demonstrated that the implementation of GL activities in the supply and transport chains would significantly improve the economic profitability of enterprises, build customer trust and satisfaction, and improve economic performance, while also making business operations smoother and more efficient, thereby enabling sustainable development. Chu et al. [101] stated in one of their studies that although GL would increase investment and training costs in the beginning, it would optimise costs and energy consumption in the long run in all stages of operation, in accordance with sustainable development criteria. In their research, Nguyen et al. [102][103] suggested the possibility of creating a green seaport as a means of lowering CO_2 emissions while also contributing to the intelligent and more environmentally friendly development of transportation in this area. Other studies have shown that an improvement in the image of an enterprise leads to a special competitive advantage in the market [28][104][105]. a business goal of minimising negative impacts on the environment and society can not only significantly reduce operating costs, but can also ensure the satisfaction of loyal and potential customers [100][105][106]. Tuzün et al. [107] reported that GL could help improve business and commercial activities while increasing the favorability of the organisation's image, which could increase market share, while enabling the company to use resources efficiently and to recycle them. In their pioneering research, Patra [105] and Evangelista [108] showed that there are four main benefits to implementing GL: reducing emissions (especially CO_2 emissions), reducing costs in the long term, reducing noise and other harmful agents to the environment, and diversifying the business and managing additional directions (reverse logistics). In one study, Zaman [109] evaluated the effects of logistics activities on economies of scale in several European countries. Research has demonstrated that the use of logistics performance indices (LPIs) for timeliness and cargo and logistics tracking systems can significantly increase the energy consumption of operations. While infrastructure improves energy efficiency and reduces CO_2 emissions, service metrics increase CO_2 significantly. Zaman [109] showed that cross-border shipments with LPIs can significantly reduce CO_2 emissions. In contrast, however, the timeliness of logistics increases CO_2 emissions. In this case, the implementation of GL has clearly not been effective. More recently, Nguyen et al. [110] evaluated the growth of smart ports and with their progress in terms of creating a sustainable maritime environment in order to lower CO_2 pollution and use energy in an efficient manner. Based on the above analysis, it could be concluded that minimising the environmental impacts of logistics activities is considered a primary GL activity, and the close monitoring of logistics flows represents the first step in this reduction.

CURRENT TRENDS IN GREEN LOGISTICS

APPLICATION OF BLOCKCHAIN TECHNOLOGY

Nowadays, the use of information technology in logistics is mandatory to avoid being left behind in a fiercely competitive market. Many enterprises have combined their information technology and supply chain management systems. Decentralised applications based on blockchain technology for supply chain management have been shown to increase performance efficiency, reduce waste, and boost customer satisfaction [111]. Sustainable supply chain management based on blockchain technology can become more honed, open, specific, and realistic if end-to-end mass customisation is implemented. Suppliers will become more productive as routine physical operations and product design planning are automated [112]. However, the application of these technologies in GL is still very limited, despite results that prove its effectiveness. Indeed, Tan et al. [113] established a framework that combined blockchain technology with GL. Their model consisted of seven layers: the physical layer, the perception layer, the network layer, the blockchain layer, the management layer, the application layer, and the user layer. Based on this framework, the authors proposed several specific applications for GL, such as tracing logistics activities and reducing the operating energy, thereby helping businesses maximise their ability to use resources, directly increasing their financial profits, and reducing the impact of operations on the environment.

Saberi et al. [114] argued that blockchain was likely to become an important technology. Thery indicated that four characteristics of the blockchain make it suitable for contributing to a sustainable supply chain: (i) thanks to its superior traceability, the blockchain can help to reduce product recalls and rework; (ii) the blockchain makes it easy for regulators to trace products and calculate the exact amount of carbon tax that each company is required to pay; (iii) it can create incentives to engage in recycling behaviors by providing deposit-based recycling programs; (iv) it can improve operational efficiency by minimising fraud and increasing system integrity. Zhang et al. [115] designed a framework that combined the blockchain with edge computing in a design consisting of five layers: the knowledge layer, the intelligent layer, the application layer, the green supply chain enterprise layer, and the market trend layer. Each layer was separate and required hierarchical permissions, making this design very secure and reliable. Enterprise users could therefore trust green supply chains without concerns regarding security risks, which would enable green supply chain knowledge to be shared among related businesses. Trivellas et al. [116] conducted a study on green supply chains for agro-food products, and pointed out the links between green supply chains, business performance, and the ability to control environmental dynamics. Their research results once again proved that logistics and transportation networks have an extremely strong influence on business performance and sustainable development goals. When blockchain technology is integrated into operational processes, agricultural products are completely under control, and can be tracked and displayed by all licensees from farmers to distribution agents. Moreover, the traceability of blockchain technology means that stakeholders can access data consistently, with high reliability, which directly reduces unnecessary losses of resources such as raw materials, contributing to economic benefits for enterprises [113]. Rane and Thakker [117] researched the applications of blockchain technology to the supply chain in the field of procurement. The performance history of a supplier and their green impacts can be easily traced using the blockchain and IoT networks. Smart contracts and IoT can be reliable indicators for suppliers when they implement green initiatives or have good environmental performance [118]. Another issue related to green procurement is the management of raw materials and output products, and this is also a strength of blockchain technology. As mentioned above, long-term historical data and convenient data extraction can help stakeholders determine the exact origin, quality, and time requirements of a product [119]. With the aim of boosting competitive performance and advancing logistics services, Nguyen [120] also investigated the use of the blockchain in supply chain management, and provided suggestions for long-term growth based on this technology. This type of information can also help in tracking green performance and assessing the recyclability, utilisation and carbon footprint of a product. For products that require particular disposal methods at the end of their life, such as those containing graphite or hazardous materials, information can also be provided to assist stakeholders in taking appropriate action. Saberi et al. [121] highlighted these problems in their study. In general, Fig. 6 illustrates the main problems, which include intra-organisational, inter-organisational, and system-related issues, and external limitations as applying blockchain to green supply chains.

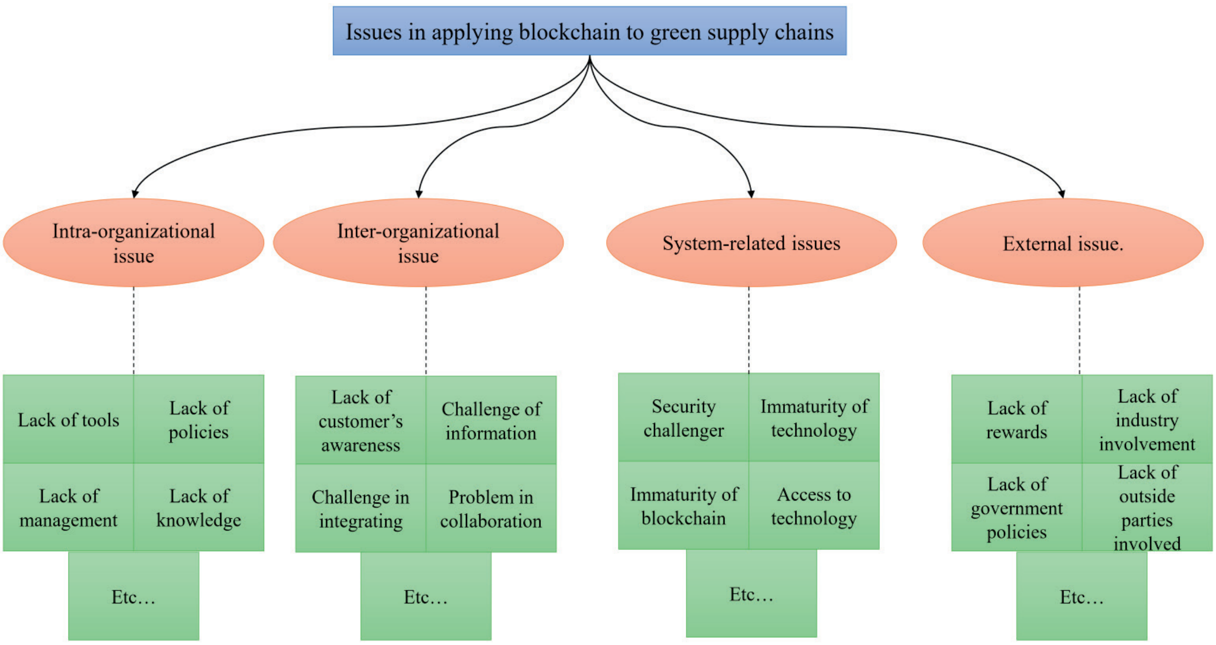

Fig. 6. Obstacles to the widespread application of blockchain technology in green supply chains [121]

USE OF ALTERNATIVE FUELS AND RENEWABLE ENERGY

After the ISO 20400 standard was introduced in 2017, the introduction of green and sustainable supply chains began to be seen as an inevitable trend. Research on green supply chain management and construction is also of particular interest. In 2018, Teixeira et al. [122] described a scenario in which green supply chain and green procurement were applied, and discussed their contributions. The two main conclusions of their research were as follows: (i) in terms of operations and organisation, supply chain and green procurement can increase the level of awareness and competitiveness in the market thanks to improvements from harmonising strategies with the strategic goals of the organisation; (ii) in terms of the environment, supply chain and green procurement can also contribute to a significant reduction in CO_2 emissions through efforts to use environmentally friendly fuel sources, and transport activities can be regulated accordingly. In addition, the use of supply chain and green procurement can help organisations to cut operating costs, improve internal communication technologies, and gradually train personnel to achieve sustainability goals [123].

It was also found that the use of alternative fuels or fuel management could be considered an efficient solution for GL, since these types of fuel could reduce carbon emissions and hence reduce environmental pollution [124][125][126]. As reported in the literature, a large number of alternative fuel types could be used for transportation means aiming to reduce pollutant emissions into the environment, such as hydrogen [127][128][129][130], biogas [131][132], biodiesel [133][134][135], LPG, LNG or CNG [136][137][138], alcohol [139][140], ether [141][142], bio-oil [143][144], and ammonia [145]. Various methods of reducing emissions from transportation means such as hydrogen fuel-cell technologies and phase change materials, have also been presented in the literature [146][147][148]. This technology converts energy directly from a fuel (such as liquid hydrogen) into electricity via an electrochemical process in a fuel cell, and then supplies it to an electric motor [149]. Fuel cells produce electricity directly from liquid hydrogen as input, with water as a by-product, meaning that under normal conditions, a hydrogen fuel cell has no negative impact on the environment and releases only water [150]. For example, in the maritime field, Geertsma et al. [151] carried out a thorough analysis of the current and potential future use of conventional and advanced electrical propulsion systems by commercial vessels. The authors provided an in-depth comparison and analysis to help businesses make the best decision when switching to electric or hybrid powertrain systems for their fleets, with a focus on the configuration, electric power source, and propulsion. a report from the International Maritime Organization (IMO) identified and compared four potential fuels that could be used to replace traditional fuels in the future: biodiesel, LNG, DME (methanol–dimethyl ether), and nuclear power [152][153][154]. Another recent report from the IMO presented a comparative analysis of prospective fuels for use as alternatives to conventional fuels based on several key criteria, including a reduction in CO_2 emissions, a decrease in black carbon emissions, the capacity to reduce NOx emissions, the possibility of reducing SOx emissions, the level of technological maturity, and the time required for widespread adoption [155][156][157][158]. In general, characteristics of using LNG, dimethyl ether, methanol, and nuclear energy for maritime sectors are summarised in Table 1.

Tab. 1: Summary of alternative fuels as an abatement option (NR: not reported)

Abatement measure	↓CO2 %			↓BC %			↓NOx	↓SOx	Technology maturity	Uptake time	Remarks	Ref.
	Low	Mid	High	Low	Mid	High						
Biodiesel – 100%	–5	NR	–11	50	NR	75	No	Yes	Demonstration	<12 months	Fuel availability	[155] [159] [160] [161]
Biodiesel – 20%	–1	NR	–3	10	NR	30	No	Yes	Demonstration	<12 months	Fuel availability	[155] [160] [162] [161]
LNG	15	NR	30	88	NR	99	Yes	Yes	Commercially available	1 to 5 years	Engine/fuel storage retrofit. Port supply of LNG. Fugitive emissions	[155] [163] [164] [165]
Methanol/ DME	NR	–9	NR	NR	97	100	Yes	Yes	Demonstration	5 to 10 years	Fuel storage retrofit and onboard catalysis units required	[155] [166] [167]
Nuclear	NR	NR	95	NR	NR	95	Yes	Yes	Not available	>10 years → Unlikely to be implemented	Design, security, and waste issues. CO2 and BC emissions from fuel production/ disposal	[155]

Besides the alternative fuels mentioned above, renewable energy has also emerged as one option for solving problems related to the demand for reducing greenhouse gas emissions and it is attracting the significant interests of all countries, scientists and policymakers [168][169][170]. Therefore, the use of renewable energy is also found to play an important role in GL and green supply chains aiming to attain net-zero goals [171][172]. Of these types of renewable energy used for maritime sector (ships and ports), the most prominent are wind and solar power [173][174]. In the maritime sector, research in the field of wind power has often focused on the application of wind-driven propulsion systems [175][176]. The use of this particular engine variant has gained in popularity as a viable solution for mitigating carbon emissions in the maritime and logistics industries [177]. Specific conditions, such as ships traveling at slow speeds (less than 16 knots) and ships with small loads (e.g., 3000–10,000 tons), were considered in studies by Smith et al. [178][179], and it was found that wind-assisted propulsion would help ships move more smoothly. One of the few commercially successful products has been the SkySails propulsion system, which consists of a towing kite tied to a rope that propels the ship forward in the direction of the wind. According to its manufacturers, the SkySails system can reduce the fuel consumption of ships by up to 50% under optimal weather conditions, and can yield reductions in annual fuel consumption of between 10% and 15% on average [180]. Besides wind, solar power is one of the most widely researched types of renewable energy for transportation and logistics. Merchant ships using solar power have been proven to have reduced CO_2 emissions [181][173]. In a study by Karatuğ et al. [182], a special type of ship called a RO-RO was also examined in terms of the arrangement of solar arrays during the trip between Pendik, Turkey and Trieste, Italy. a favorable result was obtained, as 0.312 tons of SOx, 3,942 tons of NOx, 232,393 tons of CO_2, and 0.114 tons of PM were prevented from being emitted into the environment. In addition to these two forms of renewable energy, other types should be mentioned, such as biomass, hydrogen, and geothermal energy that could be used for ports, this could also contribute to the reduction of total greenhouse gases for supply chains [183][184].

DESIGN OF GREEN CLOSED-LOOP SUPPLY CHAIN

Traditional supply chains start with the import of raw materials, pass to production and processing, and end with distribution to customers. When the demand increases significantly but technologies cannot keep up, these traditional supply chains are shown to have many shortcomings, especially with regard to environmental aspects [185]. In addition to the most obvious cause, which is the amount of emissions released by transportation into the environment, a great deal of waste such as plastics and certain difficult-to-treat materials in the supply chain do not yet have effective treatment measures. If a closed supply chain could be designed, reasonable solutions to dealing with the waste created by the production process could be found, which would significantly contribute to improving the environment [186]. Moreover, a closed supply chain can help businesses get input from recycled materials, thereby helping to improve profit margins. According to Govindan et al. [187], a closed supply chain can provide two benefits: firstly, it can ensure that the customer's needs are met, and secondly, the after-use waste products from customers' products can be collected and the most suitable treatment measures can be offered. Fig. 7 illustrates a closed supply chain consisting of a forward supply chain (raw material import, processing, assembling, distribution/retailing, and consuming) and a reverse supply chain (repairing, reconditioning, remanufacturing, recycling, and disposing), operating in parallel.

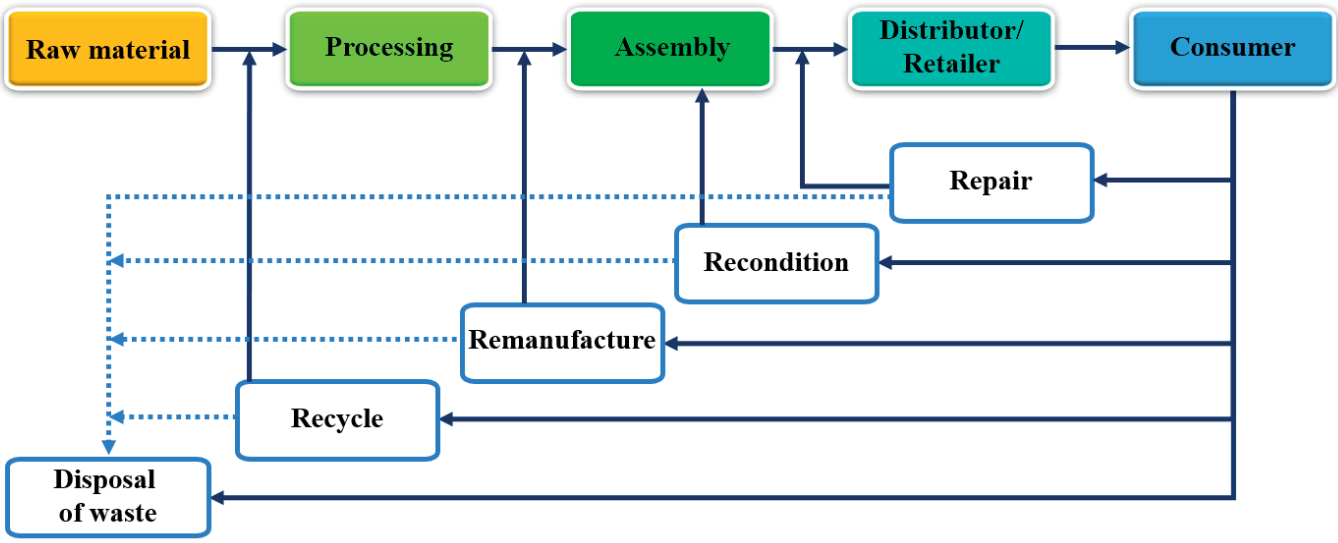

Fig. 7. General illustration of a closed-loop supply chain [188]

Soleimani et al. [189] addressed the research gap by creating a completely closed supply chain. a multi-level, multi-product, and multi-stage closed-loop supply chain was designed in which product ingredients and raw materials could be identified. This model was shown to generate both high profits and customer satisfaction, as it was possible to easily meet the customer's needs while still meeting strict requirements and maintaining responsibility for the environment and society. The results of the study were promising, which can provide a solution with small errors at the appropriate time. The model was tested under six randomized scenarios, and the results for each were presented. Mohtashami et al. [190] studied a green supply chain that included two forward and reverse phases. The model was shown to reduce the negative impact on the environment while reducing the energy consumption of transport fleets by accounting for loading/unloading and production rates, which directly affect lead times and delivery. Some small-scale computations were also discussed based on the NLP model. In addition, on a larger scale, a metaheuristics approach was applied to problem-solving. Zhen et al. [191] researched a green and sustainable closed-loop supply chain network with uncertain needs. This study applied a stochastic bio-objective mixed-integer programming approach to optimise and balance the cost and CO_2 emissions in the closed-loop supply chain network. Experimental results verified the effectiveness and feasibility of the proposed model and method. In the same area of research but with a different approach, Yavari et al. [192] addressed the problem of perishability in products, unexpected events that cause delays in the supply chain, and grid-related problems, and the authors recommended strategies for building a green closed supply chain. Five different strategies were suggested for overcoming disruptions: (i) the use of an intermediate facility; (ii) lateral transshipments; (iii) stockpiling; (iv) capacity storage; and (v) the integration of interdependent networks. The results showed that combining a strategy of integrating interdependent networks with the other strategies mentioned above, especially the first and second, could greatly improve the efficiency of the integrated network. In addition, the product was found to have a longer lifespan and the overall performance of the proposed model was enhanced, which confirmed the ability of the supply chain to respond to disruptions in the power grid using the tactic of integrating of dependent networks.

PERSPECTIVES AND PROSPECTS

In the past, industrialisation and modernisation have created some negative impacts on the environment, and the rapidly increasing trend towards globalisation in most countries has made the situation even worse, especially in terms of greenhouse gas emissions and waste [193][194]. The implementation of green and smart supply chains would optimise the entire operation process, thereby reducing adverse impacts on the environment, moving towards the goal of sustainable development, and balancing the goals of economic development, social stability, and environmental protection. With unexpected effects in both economic and environmental terms, the GL system was oriented to popularise in the supply chain from the perspective of sustainable development. The synthesis and analysis of recognised studies in the GL and supply chain sectors reveal proven and applied implementation methods as well as regulatory principles on sustainability issues that have been built and are gradually being completed [195]. However, a unified and widely accepted principle in the field of GL has yet to be adopted, meaning that the systems, methods, and tools needed to implement this process are still inconsistent. At the present time, the benefits of Industry 4.0 technologies are gradually becoming clear to businesses, with logistics being one of these. a combination of GL and smart logistics on a traditional logistics platform is forecast to be a likely direction; however, several difficulties in this area were identified in a study by Edirisuriya et al. [196]. Table 2 summarises current challenges in regard to combining and transforming traditional logistics, sustainable logistics, and smart logistics.

Tab. 2: Difficulties faced by the logistics business in the shift towards 4.0 technologies [196]

Reference	Training and development	Infrastructure and network services are being built	Adaptability of technology	Standardisation, collaboration, and government oversight
[197]		x	x	x
[198]	x	x	x	x
[199]	x	x	x	x
[200]	x	x	x	x
[201]	x	x	x	x
[202]	x	x	x	
[203]	x	x	x	x
[204]	x	x	x	

The logistics industry is also largely responsible for the problems of environmental degradation, as the main fuel used for these operations is still fossil fuels [205][206]. Regulatory organisations and governments are putting pressure on the logistics industry to implement measures to reduce or even completely replace procurement, storage, packaging, and delivery processes that have adverse effects on the environment [207][208]. The concept of GL was developed in this context and has become increasingly popular, as it refers to the use of environmentally friendly methods in the field of logistics and supply [209]. In order to promote the popularisation of GL systems, a number of studies have proposed and established tactical models as a solution to mitigate negative environmental effects. Pishvaee et al. [210] built a bi-objective credibility-based fuzzy mathematical programming model for GL systems with uncertain initial conditions. This model could help to balance the total cost of setup with the accompanying environmental factors, thus helping businesses choose the right solutions. The model included the full range of supply chain elements, including CO_2 emissions, material reuse and recycling, waste handling, and energy efficiency. Abduaziz et al. [211] built an integrated model based on systems dynamics and discrete event simulation, which could assist decision-makers in gaining an intuitive view of the environmental impacts as well as the necessary costs.

As mentioned above, research on GL and supply chains has been widely published in recent decades. However, without the determination of managers and governments around the world, it would have taken a long time for the approaches reported in these studies to be put into common use. In addition to dialogue between authorities, residents and entrepreneurs, influencers also need to continuously focus on changing people's perceptions of the environment and society [212]. Governments should continuously emphasise the importance of the environment and society in order to change perceptions, while developing and perfecting mandatory standards for logistics and supply chain activities. Zhang et al. [213] showed that although GL policies were related to many different aspects, they could be divided into two main types: (i) efficient fuel use and emission reductions; and (ii) methods of evaluating and building complete GL policies. Finding alternative energy sources during the operation of the supply chain can not only bring sustainable development to a country but also help to increase the country's energy security, as economic benefits can be gained by exporting energy [214]. Hence, more and more governments are paying special attention to GL, as reflected in policies to promote activities such as taxation or recycling. According to statistics from Liu et al. [215], innovative strategies have helped to reduce the environmental pollution of the logistics industry significantly: for example, the emissions generated by vehicles decreased by 26.9%, and green packaging and green warehouse data systems were updated, meaning that the accuracy of the transferred information increased to 45.97%. By cutting unnecessary costs and improving profit margins, businesses at the forefront of building GL systems could also become leaders in the development of the logistics industry in the future. Zhang et al. [216] reviewed and evaluated policies, public support, laws and regulations, green awareness, green technology innovations, consumer demand, and the quantity and quality of GL talent as the most important factors. Social factors shown through government support were a necessary condition for the general development of the entire logistics industry. However, support for GL facilities was a sufficient condition to develop GL comprehensively. These authors noted that enterprises needed to build and develop smart logistics systems, integrating technologies that do not pollute the environment, and needed to upgrade existing facilities in a goal-friendly direction with the environment. New facilities need to be carefully and scientifically planned based on the current state of the existing facilities, to avoid wasting time, money, material and effort, which was contrary to the existing facilities' original goal. Information technology, and especially information management, needs to be applied in the supply chain to help improve the speed, accuracy, and transparency of information circulating in the system. The ability to easily set up plans or real-time schedules can help stakeholders to be in a state of complete information awareness and to provide the most appropriate and accurate solutions, thereby reducing the cost of logistics activities [217][218]. In addition to barriers related to technology, information technology, policy, and awareness, the geographical location of production facilities and logistics centres is also a barrier that needs to be addressed by local planning regulations, governments, and planners [219][220][221]. When determining the location of logistics facilities, there is a need to consider many factors, such as the geographical locations of site selection points and demand points, economic cost, service efficiency, and consumer satisfaction [222][223].

Despite these barriers, the move towards GL is a significant trend in business. With the goal of sustainable development for industry and society and to create a better public image, businesses are making great efforts to transform. With support from modern technologies in the era of Industry 4.0, logistics and green supply chains are becoming more efficient, and represent a promising solution to the problems facing humanity. Making the world's supply chains more sustainable and reliable could go hand in hand with the common development of the world.

CONCLUSIONS

Environmental issues are a top concern in modern society because of the impact they have on all countries around the world. In particular, logistics and supply chain activities have made this problem worse due to increasing demand for transportation. In order to solve key environmental problems, this article specifically presents the current global green supply chain development trends. The application of blockchain technology allows product traceability, control, and tracking to the end of the life cycle, which is very effective in saving operating energy, materials, raw materials, and the ability to control environmental dynamics. The trend toward using alternative fuels and renewable energy shows high efficiency in reducing harmful emissions to the environment. The green closed-loop supply chain helps to improve efficiency in the recycling and processing of products as well as ensuring the supply of raw materials for the supply chain, which has been highly effective in improving the environment. These trends have significant effects on the development of green supply chains, contributing to the sustainability of the supply chain and the environment. In addition, this work also indicates the difficulties that businesses and governments face in implementing work towards green supply chains and logistics, such as limited technology and renewable energy policies in many countries or inadequacies in logistics center connection planning, suggesting that policy studies that are tailored to the unique characteristics and circumstances of each country and region should be critically conducted.

Last but not least, the close and strategic combinations of green technology and policy are found to play an important role in applying and expanding logistics activities in green supply chains. In the future, combining models between public policies and advanced technology, as well as assessing the risks of applying advanced technologies to green supply chains should be considered as potential studies.

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