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Multicriteria Assessment of Green Logistics in Taiwan’s Maritime Freight Transport: Green Packaging and Green Transportation as Driving Aspects

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ABSTRACT: This study aims to establish a multicriteria-based model for understanding green logistics in Taiwan's maritime freight transport industry. Prior studies have emphasized certain successful results from using green measures on the operational logistics operations, including establishing a competitive advantage and economic benefits. However, the literature tends to be inadequate and fragmented when discussing how green logistics relate to environmental sustainability. This study proposes a framework containing 5 aspects and 35 criteria. The fuzzy Delphi and best-worst methods are adopted to evaluate the validity and reliability. A decision-making trial and evaluation laboratory method is used to examine how the attributes’ interrelationships. The results reveal that green packaging and green transportation become the determining aspects to enhance green logistics. The top five criteria to prioritize is presented including product life cycle impact, green packaging material, use of energy at facilities, intermodal transport, emissions of transporting vehicles within the area of facilities.

1 INTRODUCTION

Green logistics (GL) refers to investing in internationally standardized green technology in logistics activities with the aim of reaching sustainable development goals especially those that concern the environment and human health [1,2]. Prior studies have highlighted some effective outcomes from applying green approaches to the logistics operational activities including gaining economic advantages and a competitive edge, by focusing on the strategy of managing the distribution movement of all the material along the chain, product inventory management, operational activities within the relevant facilities, social responsibility, and packaging treatment, all to lower the environmental impacts [3-5]. Nowadays, GL has gained great attention since the negative impacts of the maritime freight transport industry became increasingly prominent through pollution in the surrounding sea and inland environment and human health degradation [6-8]. In Taiwan, the maritime freight transport industry has shown a drastic transformation in recent years due to the fluctuating global conditions and recently experienced an increasing demand for the container shipping market influenced by the global economic activity leading to an increase in adverse effects on the environment [9-11]. As an effect, the industry has contributed to lowering air quality, especially in cities where ports are located through airborne pollutants at an endangering level that harm both the environment and human health; some of the causes include a substandard choice of fuels and conventional use of energy from facilities to ships while berthing [12]. In addition to airborne pollution, due to improper control and monitoring, Taiwan also suffers from marine pollution with solid material waste from freight transport [13]. Thus, this study argues that GL offers a potent effect to eliminate the impacts that are caused by maritime freight transport activities in Taiwan.

It is crucial to successfully balance social, environmental, and economic goals throughout all logistics activities, including transportation, storing, packaging, discharging, and processing, as the environmental externalities of logistics operations—which are mostly associated with greenhouse gas emissions, noise, and accidents—are something that GL seeks to minimize [14-16]. A collection of interconnected operations is embodied involving inventory management and freight transportation, material and packaging handling, maintenance of facilities, and internal organization social enhancement, all of which are necessary to move items through an effective supply chain process [17,18]. Although the literature has addressed GL and its implications on those operations, shortcomings remain found [14,17,19]. For instance, Trivellas et al. [20] argued that despite the extensive literature on GL, studies on its relation to sustainability performance tend to be fragmented and incomplete. Nevertheless, the shortcomings are mostly concentrated on finding the determining attributes that foster GL development.

For instance, there have been inconsistent findings regarding the attribute significance of green social performance, packaging, inventories, facilities, and transportation in affecting GL [15,21,22]. In particular, on one hand, Trivellas et al. [20] claimed that green packaging is a significant GL initiative for reducing the environmental impact and improving operational efficiency; however, on the other hand, other studies claimed that it is the green transportation that becomes the causal aspect due to the apparent emissions to the environment [3,5,14]. In addition, different other studies have highlighted that, among the significant attributes, green social performance plays a notable role in ensuring GL adoption and development acceleration in managing environmental risks [19]. Yet, Liu & Ma [16] argued green facilities are the determining attribute that potentially accelerates GL. Thus, these inconsistencies in understanding the crucial attributes of developing GL indicate a call for further investigation.

In practice, GL in the maritime freight transport industry seeks to minimize the environmental hazards and social concerns due to the flows of logistics and maritime operations of vessels in navigation and visiting the port [5,23]. For example, from the operational perspective, the emissions of transport units near the facilities such as ships stem from the engines that are kept on while moored, from the use of energy powered from onshore facilities, and heavy fuel oil (HFO) used by ship engines containing high sulfur [14,24,25]. According to Svindland [25], the current average use of HFO is 2.7% which is lower than the global sulfur cap of 3.5%, even though the limits have been restricted to 0.1% for ships that enter Emissions Control Areas. From the social perspective, Agyabeng-Mensah et al. [19] argued that there needs an improvement of an organization's reputation via the adoption of measures that protect society and the welfare of employees while meeting environmental standards. Moreover, the social perspective concerns issues about health and safety, training and education to improve skills, equal opportunities policy, child labor, and forced labor. However, these studies were conducted separately and thus showed mixed results causing inconsistent and segmented conclusions. Further, the interactions among the GL attributes and their influence on improving the GL performance are underexplored. Thus, this study incorporates multiple criteria to determine the drivers in developing GL for the maritime freight transport industry.

Prior studies have examined the attributes to construct and improve GL using both qualitative and quantitative methods [22,26,27]. Yet, there is a missing understanding in confirming the main GL driving attributes, exploring the causal interrelationship among the aspects and criteria, and identifying the significant ones. A hybrid method is applied to address the shortcoming, involving the fuzzy Delphi method (FDM), fuzzy decision-making trial and evaluation laboratory (FDEMATEL), and best-worst method (BWM). FDM is effective to select and validate the important criteria using the linguistic preferences of the panel of experts [28]. FDEMATEL is exploited to understand the driving aspects and criteria while identifying the causal interrelationships [29]. BWM is adopted to check the attributes' consistency to confirm the reliability based on a pairwise comparison [30]. The following are the study's objectives.

- To use qualitative information to create a valid set of GL attributes
- To investigate the causal-effect interrelationships between the GL attributes under uncertainty
- To determine the most important criteria for enhancing GL in the maritime freight transport industry.

The following contributions are separated to the theory and to the industry: (1) confirming a valid set of GL attributes, (2) identifying the GL attributes causal interrelationships, and (3) giving practitioners of maritime freight transport useful and practical.

2 LITERATURE REVIEW

This part presents the theoretical arguments and attributes of GL based on the proposed framework, GL in maritime freight transport, proposed measures, and the proposed method.

2.1 *Theoretical background*

2.1.1 *Green logistics*

GL is defined as the process of transportation, storage, and distribution which seeks to fulfill consumer demand while reducing the environmental impacts and optimizing product profitability from the source to the point of consumption [31]. GL involves greening the logistical functions including transportation, supporting facilities, inventories, packaging, and social performance [4,15,22]. According to Agyabeng-Mensah et al. [19], GL supposedly exchanges information with those involved in transporting commodities around the supply chain. According to Mohsin et al. [31], the important goal of GL is to conserve the environment by reducing the detrimental consequences that logistics operations have, all while successfully reducing environmental destruction and operation costs and enhancing the competitiveness of the goods and services. Liu & Ma [16] asserted that in addition to environmental problems, a lack of GL adoption might result in high logistical costs, which would raise the overall societal costs of economic growth and provide risks to human health owing to a polluted environment. There are a few benefits that have been found that might help GL possibly minimize environmental harm and operating expenses while increasing energy savings and freight and service competitiveness through decreased carbon emissions and waste [31,32].

Yet, despite the potential advantages of GL in reducing the environmental impact and logistics costs, the literature has identified some shortcomings in investigating GL. For instance, Trivellas et al. [20] argued that there is a complexity in understanding GL because the logistics functions are interdependent making it challenging to measure the sustainability in all the areas. de Souza et al. [18] criticized that GL tends to have an overlapping definition with reverse logistics and that the two should be separated by the activities; for example, while reverse logistics includes recycling, remanufacturing, and reusing packaging, GL should be focused on packaging reduction, emissions, and impact minimization. Moreover, prior studies highlighted that GL is understudied in understanding its role in sustainable development and underexplored in the context of transportation facilitation [33]. Therefore, to understand the attributes that build an effective GL model, this study incorporates the relevant logistics activities including green social performance, green packaging, green inventories, green facilities, and green transportation.

2.1.2 *Theoretical structure and measures*

In measuring and understanding GL, this study incorporates the theoretical aspects of green social performance, green packaging, green inventories, green facilities, and green transportation. Each aspect contains a number of criteria that describe the aspect and measure GL from the industrial point of view.

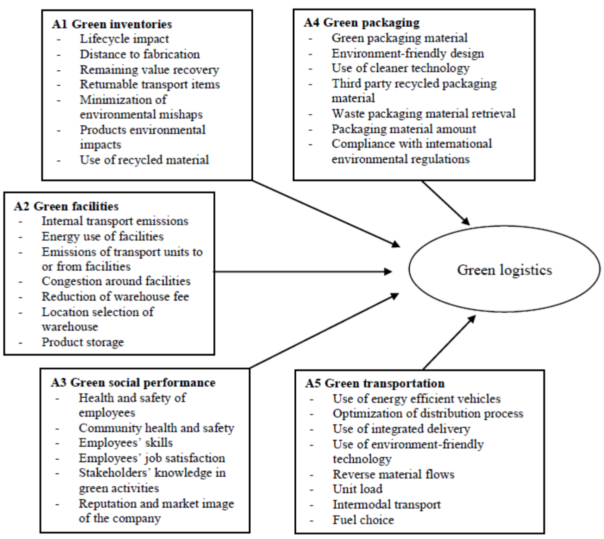

Figure 1. Proposed framework of green logistics measures

3 MATERIALS AND METHODS

This section presents the GL in maritime freight transport, the industrial background of maritime freight transport in Taiwan, and the application of methods including FDM, BWM, and FDEMATEL.

3.1 *Green logistics in maritime freight transport*

GL in maritime freight transport has been understood as environment-oriented logistics activities that are outlined with maritime transportation, logistics, and supply chain management consisting of transporting freight or cargo between two ports by waters [7,11,34]. In addition to its orientation to the environment, studies have suggested that advances and investment in green technology in the freight transport logistics systems bring certain competitive advantages of international trade globally such as efficiency in the transportation and distribution systems and long-term cost savings [2,35]. However, some GL studies in maritime freight transport often neglect the external costs in both reducing the transportation costs such as freight value and inventory cost, and boosting profitability, economic productivity, and efficiency [1,36,37]. For instance, Facchini et al. [38] argued that there are many factors that affect the logistics efficiency in freight transport such as congestion of berth, unreliable vessel schedule, and lack of docks at some marine terminals. This study suggests that the adoption of GL in maritime freight transport inherently eliminates those hindering factors. Moreover, Agyabeng-Mensah et al. [19] emphasized a lack of industry range in GL where the existing studies are focused on manufacturing enterprises creating a limit in generalizing the conclusions and ignoring other industries that contribute considerably to environmental pollution.

3.2 *Data collection*

Experts' linguistic preferences are assessed based on the critical GL attributes using the FDM, BWM, and FDEMATEL. After combing the literature of prior studies for proposing the initial GL attribute set of aspects and criteria, to communicate the information and expert system dependability, both online and in-person interviews are carried out. Questionnaires are prepared and provided to collect the experts' linguistic preferences. Using a purposive sample approach, a panel of 17 experts is selected based on their high level of expertise, familiarity with GL and maritime freight transport, and position within the firm. The panel involves 12 practitioners and 5 academics and researchers. Appendix B presents the experts' details.

3.3 *Fuzzy Delphi method*

The classic Delphi and fuzzy theory approaches have been merged to create the fuzzy theory- Delphi method (FDM), which aims to resolve ambiguity in the experts' consensus while expediting the inquiry [28,29,39]. FDM is used because of its ability to handle the fuzziness of expert assessments, which enhances the effectiveness and quality of the questionnaire [40].

Table 1. Transformation of linguistic terms

Linguistic terms based on importance level	Corresponding TFNs
Extreme	(0.75, 1.0, 1.0)
Demonstrated	(0.5, 0.75, 1.0)
Strong	(0.25, 0.5, 0.75)
Moderate	(0, 0.25, 0.5)
Equal	(0, 0, 0.25)

3.4 *Best-worst method*

The best and worst criteria for each aspect are compared pairwise with the other criteria using the BWM, a multi-criteria decision-making approach, to determine weights [30]. The method weighs the criteria to identify the best and worst.

3.5 *Fuzzy decision-making trial and evaluation laboratory*

FDEMATEL combines fuzzy set theory and the conventional DEMATEL method. The combined approach works well to identify connections between the attributes and order them according to how much of an impact they have on one another, both causally and effectually [41]. The fuzzy set theory works well for converting the linguistic preferences into crisp values when using this approach since the anticipated responses depend on the expertise and experiences of the expert panel in the form of linguistic preferences, as demonstrated in Table 2.

Table 2. Corresponding triangular fuzzy numbers' linguistic preferences

Linguistic preferences based on influence level	Corresponding TFN
Very high influence (VHI)	(0.75, 1.0, 1.0)
High influence (HI)	(0.5, 0.75, 1.0)
Medium influence (M)	(0.25, 0.5, 0.75)
Low influence (LI)	(0, 0.25, 0.5)
Very low influence (VLI)	(0, 0, 0.25)

3.6 *Proposed analytical steps*

This study proposes analytical steps, as follows.

1. Based on a review of the past literature, the initial GL attribute set of attributes and criteria is presented.
2. For validity, a questionnaire is used to collect the experts' preferences using FDM for confirming and validating the GL hierarchical structure.
3. For reliability, BWM is employed to check the reliability of the aspects and criteria that measure GL. Using the highest and lowest weights of each element, the FDM findings are used to determine the best and worst criteria.
4. For cause and effect interrelationships, the FDEMATEL is used to discover the crucial requirements for creating GL practices in Taiwan's marine freight transport as well as to identify the hierarchical structure's causal interrelationships. The crisp values are calculated and arranged into initial direct relations. Then, a map is created to visualize the cause-and-effect diagram of the aspects and criteria.

4 RESULTS

This part of the study uses the FDM to show the characteristics' validity, verifies their reliability using the BWM, and looks at how the attributes relate to causes and effects using the FDEMATEL approach.

4.1 *Validity of measures*

The initial proposed set of attributes includes five aspects containing 35 criteria as presented in Appendix A. Validation of the attributes based on the experts' assessments is conducted by removing the less important criteria, resulting in a success in producing valid four aspects and 17 criteria. The method refined the valid attributes which results in the threshold of $\gamma = 0.6277$. Table 3 shows the valid attributes along with the passing weights and presents the renamed and reordered aspects and criteria after the elimination process. Thus, as a result, after the evaluation process, the remaining valid aspects include green inventories (A1), green facilities (A2), green packaging (A3), and green transportation (A4).

Table 3. Validated green logistics attributes

Aspects	Initial code	Renamed code	Criteria	Weights
A1 Green inventories	C1	C1	Product life cycle impact	0.6409
	C3	C2	Remaining value recovery	0.7022
	C5	C3	Minimization of environmental mishaps	0.6338
	C7	C4	Use of recycled material	0.6301
A2 Green facilities	C8	C5	Internal transport and emissions	0.6318
	C9	C6	Energy use of facilities	0.6924
	C10	C7	Emissions of transport units to or from facilities	0.6981
	C11	C8	Congestion around facilities	0.6927
A3 Green packaging	C21	C9	Green packaging material	0.7058
	C22	C10	Environment-friendly packaging design	0.6980
	C23	C11	Use of cleaner technology in packaging	0.6970
	C24	C12	Third party recycled packaging material	0.6895
	C25	C13	Waste packaging material retrieval	0.6916
	C27	C14	Compliance with international environmental regulations	0.7195
A4 Green Transportation	C31	C15	Use of environment-friendly technology	0.7053
	C34	C16	Intermodal transport	0.7035
	C35	C17	Fuel choice	0.7253
Threshold				0.6277

4.2 *Reliability of attributes*

The attributes' reliability is checked using BWM based on the best and the worst criteria under each aspect. This method is integrated with the FDM in determining the best and the worst criteria of each aspect based on the FDM weight as previously shown in Table 3; the highest weight of the aspect means the best criterion and the lowest weight of the aspect means the worst criterion.

Based on the consistency ratio (Ksi), the results reveal that the evaluated aspects show consistency as each individual value is close to zero, indicating that the criteria belong to the aspects and therefore the measures are reliable, as Table 4 demonstrates below.

Table 4. Verified reliability of green logistics measures

Aspect	Ksi
A1 Green inventories	0.321231802
A2 Green facilities	0.299065121
A3 Green packaging	0.200488998
A4 Green transportation	0.344497608

4.3 *Causal-effect interrelationships among attributes*

The driving and dependent powers are determined by evaluating the relationships between the valid attributes using FDEMATEL, which are then depicted with a graph in a cause and effect diagram. The experts provide their preferences on the interrelationships of the aspects utilizing linguistic scales.

In Figure 2, the causal group consists of green packaging (A3) and green transportation (A4), while the effect group consists of green inventories (A1) and green facilities (A2). The relationship powers vary among the aspects. For instance, A4, A3, and A2 show to have a strong effect on A1, while both A3 and A4 have a weak effect on A2.

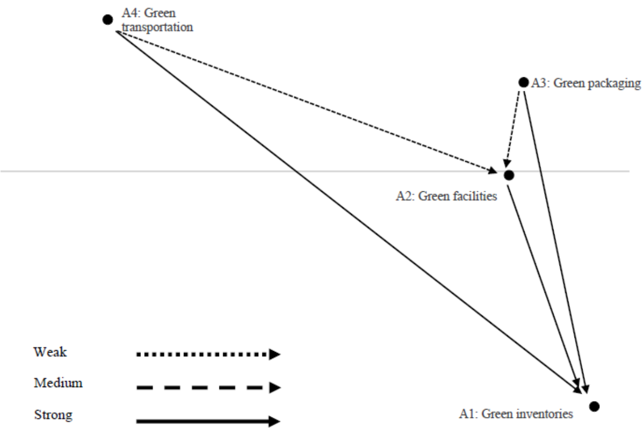

Figure 2. Cause and effect model of green logistics aspects

The identified important criteria are product life cycle impact (C1), green packaging material (C9), intermodal transport (C16), energy use of facilities (C6), and emissions of transport units to or from facilities (C7), as depicted in Figure 3.

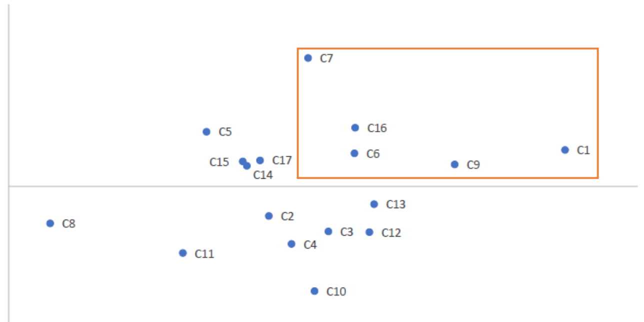

Figure 3. Causal-effect diagram for criteria

5 DISCUSSION

5.1 *Theoretical implication*

The results confirm that green packaging is a determining aspect in terms of making efforts toward improving GL. A form of packaging that considers both the preservation of the environment and the health of people and animals throughout the course of its lifecycle is referred to as green packaging. The characteristics of packaging are typically concentrated on the use of recyclable or reused materials, but they also include considerations of sizes and shapes for transportation and stacking effectiveness. Green packaging potentially rises resource use efficiency by shortening and decreasing logistics distribution routes that are otherwise taken for retrieving the raw material for new production [20]. Yet, the challenge of green packaging is to achieve the environmental goal while meeting the economic purpose of protecting and preserving the product quality and condition during the logistics processes. In this regard, the firms adopting GL in their business process are required to minimize energy use by making the packaging green through ensuring its high durability and recyclability. In addition, green packaging is ineffective unless there is support from laws and policies regulated by the government in standardizing the minimum requirement of green packaging for optimal durability and recyclability [17].

Green transportation is also a vital aspect pertaining to the causal group which stipulates the aspect's importance in strengthening GL. The aspect refers to saving energy from using any transport modes throughout the logistics operational activities [16,31]. The issue of transport choices is heavily focused on optimizing the routes while considering lowering the impacts on the environment during the deliveries [20]. Thus, this study suggests that greening transportation shall be accomplished by reinforcing multimodal transportation which appertains to highly efficient distribution routes hence energy saving. The use of clean energy and braced environmental restrictions are a few strategies to promote GL performance [22]. The highlight of transportation's role in GL is put forward due to its main contribution to emissions generation throughout the logistics processes, and therefore, by moving forward to green transportation the goal of GL to eliminate the environmental impacts in most of its operations can be achieved effectively. Further, the findings exhibit strong and moderate effects of green transportation on green packaging, facilities, and inventories, suggesting that confirming the whole GL development and execution is facilitated by greening logistics transportation.

5.2 *Managerial implication*

Product lifecycle impact in maritime freight transport refers to the environmental impacts due to the use of resources that are required to make the product. Environmental impact assessment and the Environmental Protection Agency (EPA) in Taiwan control the lifecycle impacts of products, including those moved by water, and demand that maritime freight transport companies submit strategic environmental assessment reports to the government. The main concern is the carbon footprint that is generated from production and transportation during the logistics operations which include the marine operations and those on land. Not only that the lifecycle impacts need to be reduced but also need to be properly managed, evaluated, reported, and controlled with appropriate management. Thus, logistics firms require management tactics such as adopting formal operational procedures that are pro-environment, making reports of logistics activities, evaluating the firms' performance, sharing information, communicating with the relevant stakeholders about the activities, and complying with environmental standards. Product lifecycle impacts are found in the process of producing the product yet do not end at the end-customers; if the GL concept is properly applied, the impacts are well monitored and mitigated by the logistics firms as part of the firm's environmental and social responsibility not only on the production line but more importantly during the maritime transporting activities. This is in line with the practice; the maritime freight transport industry extends the standardized lifecycle assessment by promoting freight retrieval after use and establishing an integrated system for further freight treatment such as for recycling or remanufacturing by collaborating with other logistics firms, merchants, customers, and government agencies, in order to eliminate waste generation.

Green packaging material is found to be fundamental to improving GL practices for the maritime freight transport industry, and this criterion refers to the environment-friendly material used for packaging during the distribution or delivery processes. Packaging is crucial as it serves to protect the freight damage which could lead to product and financial losses and might potentially break the relationship or trust between the customers and logistics service providers. In the maritime freight transport industry, the transported product is at risk of physical and wet damages, especially during the volatile sea conditions during the journey. Green packaging material does not only need to constitute material made of recyclates but also be less energy-requiring during production and reusable by the end-consumers after the product is received. Biodegradable and recyclable materials are recommended for lowering packaging waste generation. Regarding waste generation, this is in line with the effort from the government agency where the Taiwan EPA has collaborated with civic environmental organizations to set up the so-called Taiwan Marine Debris Governance Action Plan with a primary concern of preventing and removing waste from entering the oceans. Thus, opting for green packaging material to reduce waste is recommended for the firms. It has also been highlighted that another advantage of using green packaging material includes minimalizing fuel emissions during lengthy trips of transport; maritime freight transport firms should consider light packaging materials without neglecting the safety and protection of the product. In sum, maritime freight transport firms are suggested to ensure packaging durability, recyclability, weight, and versatility in order to implement GL.

The emphasis on the energy use of facilities in implementing GL of maritime freight transport refers to achieving zero emission in distributional facilities including ports and warehouses. In general, these facilities attribute to a fair cut of the firm's revenue due to the use of heating, cooling, and lighting as the main energy users. The installation of solar panels and the use of advanced energy-saving technology are among the common ways that have been done by many logistics firms within their facilities. For non-temperature sensitive freight, a well-designed architectural warehouse that reduces the use of air conditioning technology can be considered, through an effective ventilation system. Overall, a proper energy management system implemented in the facilities should effectively contribute to the yearly revenue without needing to take a significant capital investment. In order to implement GL, logistics facility managers are encouraged to constantly improve the facility performance directed toward shore-power-saving while ensuring the efficiency and productivity of the operational equipment. However, adopting a shore power supply system has the drawback of necessitating investments in relevant power transmission equipment from both facility authorities and maritime freight transport firms, which raises costs. It is challenging to install an emissions control area to regulate ships and make the conversion to low-sulfur fuel in the short term. This is due to the fact that implementing such a plan would result in higher fuel prices for ship owners and would require approval from the International Maritime Organization. Thus, strategies such as lessening the downtime, extending the equipment lifecycle, and lowering the power draw during peak periods are also recommended.

Intermodal transport refers to the use of multiple carriers that use different modes of transportation to move freight from the shipper to the consignee and is facilitated with shared logistics container terminals that integrate a combination of maritime freight transport units and inland transport units. The potential advantage of such an integrated mode of transport is to save the kilometers that are otherwise generated in congested routes and thus lower the environmental impact due to lower emissions generation. Through enhanced port-to-backcountry connection, intermodal transportation streamlines the maritime supply chains for freight transport. Enhancing intermodal transport to improve the convergence of maritime freight transport and logistics requires physical, economic, and organizational integration involving the infrastructure and people. In maritime freight transport, the challenge is that the existing conventional functions of ports must evolve from enabling loading and discharging operations to becoming a crucial connection in a larger logistics chain. At the global scale, intermodal transport refers to establishing freight transport corridors that connect different continents in serving the supply chains which potentially attract higher demands worldwide. Overall, implementing intermodal transport in the maritime freight transport industry requires careful coordination, focused policies, and investments.

Emissions of transport vehicles or units that operate to or from facilities refer to emissions produced by ships or their engines while moored or operating on less efficient modes. Ship emissions are predicted to increase over the years depending on the global future economic and social conditions. The increasing emission rates are not only due to inefficiency in keeping the engines on but also driven by growing demands for freight shipping services and consumption of fossil fuels. Most berthing ships in Taiwan operate their boilers and main and auxiliary engines with heavy fuel oil, which results in severe air pollution that might have major negative health effects. In order to decrease emissions from ships at berth, an efficient mitigation and control plan must be implemented because this is neither desired nor sustainable over the long term. Moreover, the increase in demand also pushes shipping service providers to improve their performance and one way of achieving that is through speeding up for faster customer service, hence higher emissions generation. In-land transport within the warehouse facilities is also in question. For example, congestion around facilities should be reduced by taking advantage of upgraded technology toward automation, improved inventory systems, and efficient operational hours. Regulations at certain cutting-edge facilities require ship owners to abide by stringent environmental protection laws, and port authorities ban ships from using their prime movers when berthed.

In sum, due to the large carbon footprint created by production and transportation during logistics activities, including marine and land-based operations, the maritime freight transport industry has a substantial impact on the environment. This impact includes the emissions that ships or their engines create while moored or using less efficient modes. The rising demand for freight transport services and the use of fossil fuels are the main causes of the rising emission rates. Depending on future global economic and social conditions, ship emissions are expected to rise over time. In order to lessen the industry's negative environmental effects, green packaging materials must be used, and energy efficiency in facilities must be prioritized. By reducing the number of miles traveled on congested routes, intermodal transportation can also assist reduce the production of greenhouse gases. The marine logistical chains for freight transport may be made more efficient by the integration of numerous carriers and shared logistics container ports. Therefore, the magnitude of the impact can be reduced by employing appropriate managerial strategies, such as adopting formal operational procedures that are pro-environment, reporting logistics activities, evaluating firms' performance, sharing information, communicating with pertinent stakeholders about activities, and adhering to environmental standards.

6 CONCLUSION

GL develops primarily to lessen the environmental effects brought on by a series of logistical activities. Developing GL has not been an easy task due to many influencing attributes that need to be considered, yet there is a lack of studies that attempted to identify the top driving attributes. To solve the gap, this study overlooks the critical attributes by proposing an initial hierarchical model of GL attributes containing five aspects and 35 criteria to be examined using a hybrid method. FDM was used to screen and validate the important criteria through an elimination process using the average value as the threshold. By comparing the best and worst criterion pairwise, BWM was used to perform the reliability assessment. FDEMATEL was applied to determine the driving aspects and identify the top criteria to improve GL in the maritime freight transport industry in practice.

Still, the limitations of this study are present. Based on the literature, this study suggested a set of attributes and selected them based on a collective judgment of experts, which is subject to incompleteness and has the potential to be expanded by including a wider range of attributes in the future study. In addition, the future study shall consider the perspectives of the economy and government to be included in the proposed framework. Experts in shipping and logistics who have years of expertise in the field as well as in academia are involved in this study; the future study should include a proportional number of experts from the government as well. In terms of the industry, this study focuses on the industry of maritime freight transport which is unique in its characteristics. The future study should consider exploring GL in a different kind of industry to enrich the literature.

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Appendix A
Initial attributes

Aspect		Initial code	Criteria	Description
A1	Green inventories	1	Life cycle impact	Life cycle impact indicates the resources that generate carbon footprint during transport
		2	Distance to fabrication	The distance of product to its fabrication affects the carbon footprint trace
		3	Remaining value recovery	Recovering the remaining value of a product, instead of landfilling or incinerating
		4	Returnable transport items	Returnable transport and packaging supply such pallets, containers, and roll cages
		5	Minimization of environmental mishaps	Reduction of trash production, poisonous and dangerous material consumption, and environmental accidents
		6	Products environmental impacts	The environmental impacts of products
		7	Use of recycled material	The volume of recycled material used
A2	Green Facilities	8	Internal transport and emissions	If emissions from transport in container ports can be decreased, the environment will benefit
		9	Energy use of facilities	Many firms are concerned about the energy usage of buildings like warehouses, and not just for financial reasons
		10	Emissions of transport units to or from facilities	Emissions from vehicles near or inside of buildings, such as when a ship is docked and has its engines running
		11	Congestion around facilities	Peak arrival times are caused by connection times for transshipping products, and if there are any disruptions, there may be extended waiting hours
		12	Reduction of warehouse fee	Fee for using warehouse
		13	Location selection of warehouse	Selecting an optimal location of warehouse
		14	Product storage	The supply chain's design must take inventory holding costs into consideration
A3	Green social performance	15	Health and safety of employees	Improved health and safety for employees
		16	Community health and safety	Increased community safety and health
		17	Employees' skills	Improved skills of the employee
		18	Employees' job satisfaction	Improved levels of work satisfaction among employees
		19	Stakeholders' knowledge in green activities	Increased engagement of stakeholders in planning and carrying out environmental practices and improvement of their awareness of green activities
		20	Reputation and market image of the company	Enhanced company's reputation and image in the market
A4	Green packaging	21	Green packaging material	Use of green material for packaging
		22	Environment-friendly packaging design	Packaging that uses environmentally friendly design
		23	Use of cleaner technology	Packaging using greener technology
		24	Third party recycled packaging material	Use of recycled packaging acquired outside of the company
		25	Waste packaging material retrieval	Collecting used packaging from consumers for recycling
		26	Packaging material amount	Amount of packaging material to be used
		27	Compliance with international environmental regulations	Packaging that complies with international environmental requirements
A5	Green transportation	28	Use of energy efficient vehicles	Utilizing energy-efficient vehicles to increase efficiency
		29	Optimization of distribution process	Enhancement of the distribution process through improved scheduling and routing
		30	Use of integrated delivery	Using integrated delivery to cut down on travel
		31	Use of environment-friendly technology	Use of green technology in transportation
		32	Reverse material flows	Reverse material flows are managed to minimize transportation
		33	Unit load	After selecting a method of transportation, a decision must be taken on the kind and dimensions of the transportation unit
		34	Intermodal transport	Transporting freight utilizing several different means of transportation while using an intermodal container or truck without handling the freight individually
		35	Fuel choice	The selection of an environmentally friendly fuel

Appendix B
Experts' characteristics

Expert	Position	Education level	Years of experience	Expertise
1	Senior research commissioner	PhD	36	Shipping and commercial ports
2	Deputy director	PhD	29	Shipping and commercial ports
3	Deputy	Masters	12	Shipping and commercial ports
4	Manager	Masters	20	Stevedoring & warehousing
5	Head of department	Masters	10	Harbor management
6	Head of department	Masters	12	Ship & machinery
7	Supervisor	Masters	7	Stevedoring & warehousing
8	Deputy	PhD	21	Trading Policy – Ministry of Trade
9	Head of department	PhD	16	Trading Policy – Ministry of Trade
10	Head of department	PhD	12	Trading Policy – Ministry of Trade
11	Manager	Masters	13	Customs and Logistics
12	Supervisor	Masters	7	Customs and Logistics
13	Chair professor	PhD	30	Sustainable supply chain
14	Professor	PhD	22	Sustainable supply chain
15	Professor	PhD	14	Marine transportation science
16	Associate professor	PhD	11	Shipping & transportation management
17	Associate professor	PhD	9	Sustainable/Green logistics