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Article

Green Logistics Instruments: Classification and Ranking

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Abstract: The concepts of Sustainable development, Triple Bottom Line and ESG have a strong influence on the process of formation and operation of supply chains today. This requires the implementation of various green solutions and practices to improve supply chain sustainability. The analysis conducted of supply chain research has not revealed a universally accepted methodology to systematize green solutions and practices for their effective use in chain management. It was revealed that there are many views on the content of green solutions, insufficient specificity of their description, as well as fragmentation of the use of green solutions in relation to the elements and functions of supply chains (procurement, production, warehousing, transportation, distribution). This reduces the effectiveness of green solutions' implementation. In this study, based on the literature review, a classification of currently existing green solutions and practices is made. The classification is done according to the affiliation of supply chain elements and the functions performed by the elements to promote and process the material flow from supplier to consumer. The proposed system of methods (GLM) and instruments (GLI) of green logistics covers all known functional areas of logistics and includes 27 methods and 105 instruments. The paper performs a ranking of methods and instruments using TOPSIS, MABAC and MARCOS methods. The most and least significant GLM and GLI for each element of the supply chain, as well as for chains of complex structure in general, are determined. The results of GLM and GLI ranking can be used as a basis for the implementation of management decisions to improve the sustainability of supply chains.

Keywords: green logistics; green supply chain; green practices; green solution; instruments; methods; MCDM; ranking

1. Introduction

The functioning of supply chains a set of processes of procurement, production, and distribution of material flows to the final consumer. The classical concept of supply chain management synthesizes the tasks of logistics – minimization of total costs in the chain, operational management – effective inventory and production management, marketing - focus on creating value for the customer [1]. However, the intensive spread of such concepts as Sustainable development, Triple Bottom Line, ESG (Environmental, Social, Governance) all over the world is changing views and approaches to supply chain management. Along with the economic benefits of companies, the policy of people's welfare and environmental protection are an integral part of supply chains management (SCM) nowadays [2]. Companies around the world are implementing green practices in supply chain management, trying to transform supply chains into sustainable supply chains or green supply chains. National governments and company management are implementing various programs and projects to achieve sustainability goals. Green or sustainable supply chain management is one of the most relevant topics in modern research of operations management, logistics, and sustainability [2,3].

The analysis of papers in the field of green or sustainable supply chain management shows an increase in the number of scientific papers devoted to theoretical and practical problems of implementing green practices. The existing approaches can be divided into two groups. The first one is related to the research of supply chains as a single system [4–6], the second one is related to the

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research of individual green operations [7] or elements of supply chains. The latter include, for example, studies of sustainable supply [8,9], sustainable production [10,11], sustainable warehousing [12,13], sustainable transportation [14,15], sustainable consumption [16]. One of the key research questions is the challenges of implementing green solutions and practices in logistics. Such practices encompass the integration of sustainable approaches into forward and reverse logistics operations to promote balanced social, environmental and economic performance [3].

The main objective of our study is to categorize the currently used green solutions and practices in logistics activities to develop a universal system of green logistics instuments. This study makes both theoretical and practical contributions to the field of green logistics and green supply chain management. Firstly, based on the analysis of scientific publications and structural-functional approach, we have identified green solutions and practices and developed a universal system of green logistics methods and instruments. The main idea of the classification is to compare and group different green solutions and practices with the functions of structural (logistics) elements of green supply chains. Second, we developed a methodology to rank green logistics instruments in the supply chain using multi-criteria decision-making (MCDM) techniques. This methodology will help stakeholders make effective decisions to implement green logistics methods and instruments in supply chain elements based on the ranking of instruments.

The rest of the paper is as follows. The next section contains the literature review. The third section describes the methodology for systematization and ranking of green logistics methods and instruments. The fourth section presents a computational case study of the implementation of the proposed methodology. The last section contains the main results and directions for future research.

2. Literature Review

To understand the terminology used in relation to green practices in logistics and to identify the most common keywords, we used a combination of keywords to search for review articles in Scopus: “Practices” AND “Review” AND “Green AND supply AND chains” OR “Green AND Logistics” in their titles, abstracts, or keywords (Figure 1).

The analysis of articles indicated that different terms are used in the research in relation to green practices: Criteria, GSCM practices, Factors, Measures, Green logistics practices, Activities, Initiatives, Drivers, Practices, Green practices, Green activities, Decision, Attributes, Sustainable practices, Solution, Policies, GSCM initiatives, Green logistics activities, Green initiative.

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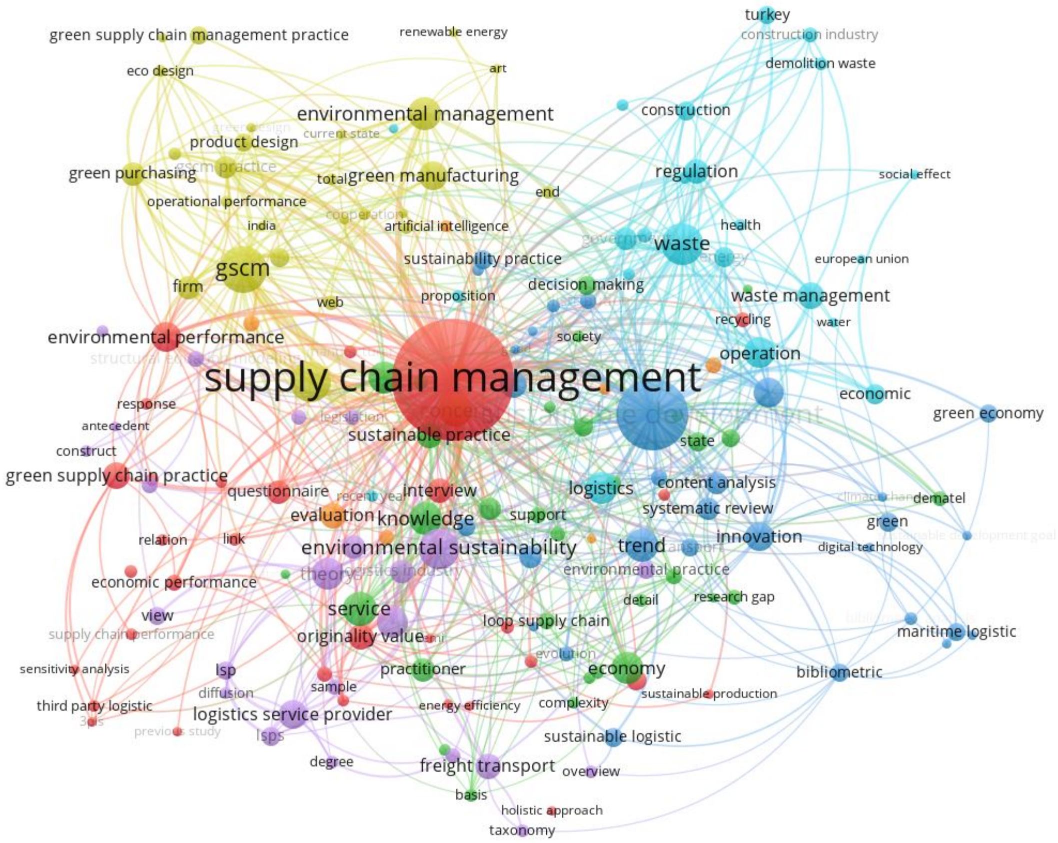

Figure 1. The network of keyword co-occurrences.

We have analyzed review papers in which the authors have attempted to group and systematize various green solutions and practices as applied to supply chain and logistics activities.

The paper [17] compares green and lean practices on supply chain management performance. The authors grouped 17 practices into two groups and presented their brief characterization of the practices. The 14 solutions are grouped into 4 types of activities: Green office, Inventory control and material handling, Green warehousing and Green transportation [18]. The authors in [19] identified three levels of dimensions and categories for different green activities and operations aimed at improving the efficiency of green logistics. The authors grouped 18 green activities and operations into three categories - Network design, Product & Inventory, Reverse logistics. In the studies [20], the authors grouped 36 activities/practices for all activities in the supply chain such as raw material procurement, inbound logistics, transformation, outbound logistics, marketing, after-sales and appropriate product disposal.

The reviews [5,21] present a list of 58 green supply chain practices that are grouped into 16 aspects of green supply chain management (GSCM): reverse logistics, industrial symbiosis, eco-innovation practices, green information technology and systems, green design, carbon management, supplier environmental collaboration, customer environmental collaboration, ISO 14001 certification, internal management, green purchasing, green manufacturing, green packaging, green logistics, green outsourcing, green warehousing. The authors [4] analyzed the frequency of GSCM practices in the scientific papers. They identified 46 different practices. The five most frequently mentioned are green purchasing/procurement, collaboration/cooperation with customers, internal GSCM practices/environmental management, green/eco-design, investment recovery. Another [22] paper identifies the major research fields in circular supply chain management and calculates the frequency of mentioning 25 alternative solutions in scientific publications. The paper [3] points out two approaches in the existing research: green logistics practices can be considered as a composite construction for improving sustainability, or publications focus on individual practices. As an example, the authors identify 33 green logistics practices: green manufacturing, green marketing,

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green consumption, green reverse logistics, green transportation, green communication, information sharing, logistics emissions, green warehouse, green packaging, green vehicle technologies, alternative fuels, eco-driving, green transport management, green logistics systems, green modal shift, eco-friendly technologies, environmental standards, green administration and logistics data management, sustainable waste management, eco-friendly transportation, waste reduction, energy-efficient operations, sustainable transport, green ware housing and building, eco-design, green purchasing, reverse logistics, responsive packaging, green monitoring and evaluation, sustainable information sharing, sustainable packaging and distribution, waste management.

In another literature review [23], all articles are categorized into two groups of mitigation actions and adaptation actions and include 7 green actions to improve environmental sustainability in third-party logistics service providers. The paper [24] attempts to identify the determinants (motivations, pressures, and incentives) and modalities (practices conducting greening transportation from shippers and logistics service providers (LSPs)) standpoint. Based on a review of publications, the authors identified 14 green logistics practices and described them. According to the authors, these practices are green modal shifts, green transportation management, green logistics systems, green vehicle technologies, eco-driving, alternative fuels, environmental management systems (EMS), reverse logistics, green administration, green packaging, green warehousing, emission data, cooperation with shippers, choice of partners.

Another literature review [25] explores the relationship between GSCM pressures, practices, and performance. The authors grouped the literature on GSCM practices — eco-design, internal environmental management, waste management, green purchasing aspect, quality, and product recovery. The authors [26] studied the relationship between Green Human Resource Management practices and Green Supply Chain Management practices.

In the systematic review [13], the papers on green practices is grouped into three macro themes: the green warehouse management, the environmental impact of warehouse construction, and the energy saving in warehousing. In the paper [14], the literature on sustainable transportation is classified into 6 decisions — network design, profit sharing, inventory, distribution organization and routing. The study [12] focuses on sustainable inventory management in green supply chains. The authors considered 25 solutions to improve the sustainability of inventory management. The paper [27] considers Industry 4.0 technologies divided by GSC aspects. The authors grouped 10 green practices into 5 aspects — reverse logistic, green design, green manufacturing, carbon emissions management and green warehousing.

In several research studies, the authors do not consider green practices as activities, but as criteria against which to evaluate individual logistics processes to improve the sustainability of the supply chain. For example, when evaluating suppliers (12 practices) [28], green practices and initiatives for sustainable hotel operations (27 attributes of green practices and initiatives for sustainable hotel operations) [29]; to assess green supply chain management (13 criteria and 79 sub-criteria) [30]; to assess the feasibility of implementing Industry 4.0 technologies in sustainable supply chains (17 criteria and 59 attributes) [31].

A review of research on the use of green practices in logistics and supply chain management revealed the following problem.

Multiple views on the content of green solutions and, consequently, insufficient systematic implementation in supply chains.

Different understanding and interpretation of green practices.

Insufficient specificity of green solutions and practices (lack of description in 71% of publications).

Fragmented use of green solutions and practices in relation to elements and functions of supply chains (procurement, production, warehousing, transportation, distribution).

3. Methodology for Systematization and Ranking of Green Logistics Methods and Instruments

The proposed methodology is based on the structural-functional approach to the green supply chain formalization. This approach defined the principles of green logistics methods and instruments

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systematization. Multi-criteria decision-making methods are used to rank the methods and instruments. MCDM and a system of criteria for evaluating logistics flows, the achievement of which ensures the fulfillment of sustainable supply chain development goals, are applied for ranking.

3.1. Structural-Functional Approach to the Green Supply Chain Formalization

The structural-functional approach involves the identification of supply chain-based logistics functions and the identification of corresponding abstract logistics elements. The basic logistics functions are proposed to include the following main actions with logistics flows (a) acceleration and movement, (b) deceleration and accumulation, (c) quality change and processing, (d) input into the system, (e) output from the system, and (f) coordination of logistics functions. The relevant logistics elements realizing these basic functions are (a) transport, (b) cumulative, (c) processing, (d) input, (e) output, and (f) control. The basic functions of each logistics element or supply chain element are concretized by a set of so-called supporting functions, i.e. specific actions to change the parameters of logistics flows.

With the help of a combination of abstract logistic elements realizing the corresponding basic and supporting functions, it becomes possible to model any real infrastructural element of the supply chain. It becomes possible to formalize supply chains or logistics systems at any level of detail.

The structural-functional approach is fundamentally different from the generally accepted way of identifying functional areas of logistics, such as transportation, sales, production, supply and warehousing logistics. The disadvantage of the traditional functional approach is the "binding" of logistics functions and operations to infrastructural elements of logistics chains – warehouses, industrial enterprises, supply and sales departments, transportation. This makes it difficult to identify and systematize the methods and instruments of logistics flow management, since the same method or instrument can be implemented in different functional areas of logistics [32].

The model of the green supply chain (GSC) formed using the structural-functional approach is presented in Figure 2. The GSC model is a set of logistics elements linearly ordered along with the material and accompanying financial, information and work (sevice) flow. Achievement of sustainable development goals is ensured as a result of fulfillment by each GSC element of its supporting functions with the help of green logistics methods and instruments Figure 3.

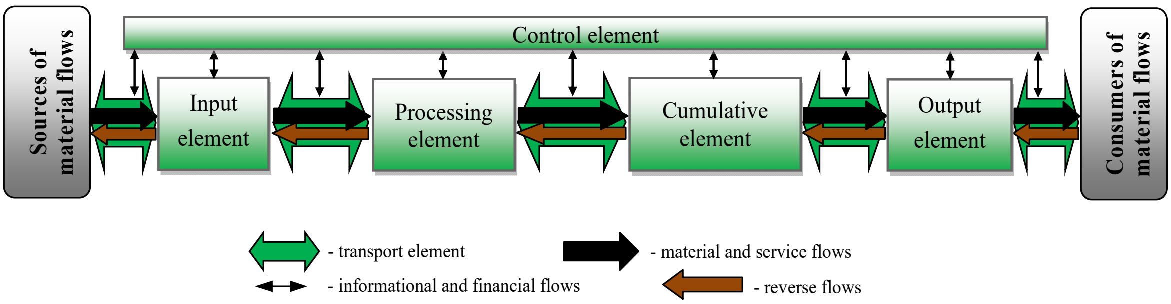

Figure 2. Green supply chain model according to the structural-functional approach to the identification of logistics elements.

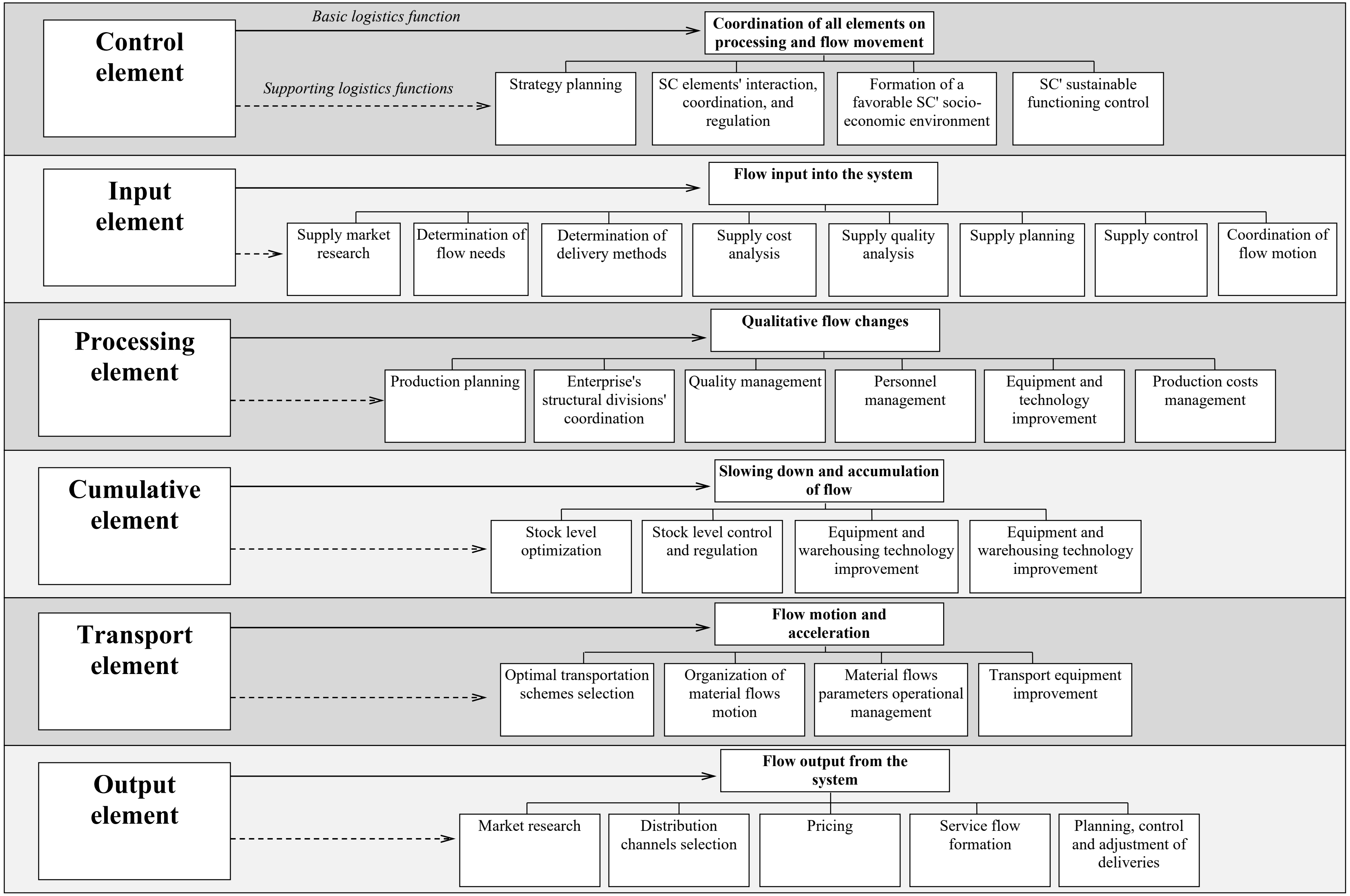

Figure 3. Basic and supporting functions of green supply chain elements.

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3.2. Classification of Green Logistics Methods and Instruments

The study of scientific literature has allowed us to establish that different terminology is used in relation to solutions to reduce negative environmental impact in logistics. The most common terms are “green practices”, “GSCM practices”, “green factors”, “green measures”, “green activities”, “green initiatives”, “green drivers”, “solution”, etc.

We propose to use the terms “green logistics methods” and “green logistics instruments” as generalized concepts for various green solutions in the field of logistics activities. The main purpose of implementation of green logistics methods and instruments is to identify and eliminate deviations of their parameters that hinder the achievement of Sustainable Development Goals (SDGs).

In the previous paper [33], we proposed a system of green logistics methods and instruments. This system consists of 27 methods and 105 instruments. We have established what specific SDGs are achieved by the realization of each method and instrument. Subsequent studies [32,34–38] allowed us to clarify, adjust and extend the original system by a detailed description of each instrument.

The classification of methods and instruments presented in this study is made using the following classification features:

- Correspondence to the elements of the supply chain to avoid duplication of methods and instruments at different stages of the logistics process, as well as to identify missing and promising methods and instruments.
- Correspondence to supporting functions of supply chain elements. Traditionally, logistics functional areas are focused on cost reduction and quality improvement. Specialization of green logistics methods and instruments by supporting functions is necessary to achieve social and environmental goals additionally.
- Correspondence of instruments to the green logistics methods, i.e., realization of a certain method by a set of instruments.

In addition, the proposed classification is based on the following principles:

- Consideration of green logistics methods and instruments as a unified system for achieving SDGs. The object of management is logistics flows in the supply chain.
- Using the best green practices, eco-programs and projects with the participation of political, social and economic institutions, scientific organizations, international unions and organizations to form and improve the system of green logistics methods and instruments.

Thus, we propose the following concepts:

- ***Green Logistics Method (GLM)*** – a set of solutions to achieve the SDGs by realizing the basic and supporting logistics functions of a certain element of the logistics system or supply chain.
- ***Green Logistics Instruments (GLI)*** – a specific solution for changing the parameters of logistics flows to implement the corresponding green logistics method.

3.3. Multi-Criteria Ranking of Green Logistics Methods and Instruments

A GLM and GLI system can consist of multiple methods and instruments specialized by logistics elements and functions. Different elements of the supply chain may have different objectives in changing the parameters of logistics flows by GLM and GLI. Therefore, ranking and selection of GLM and GLI is proposed to be done using multi-criteria decision-making (MCDM) techniques.

The methodology for multi-criteria assessment and ranking of GLMs and GLIs consists of the following steps:

Step 1. Design a list of methods and instruments based on the results of analyzing scientific papers in the field of green solutions and practices as applied to supply chains.

Step 2. Formation of GLM and GLI system with observance of classification attributes and principles presented in Section 3.2. Grouping GLM by supporting functions of logistics elements. Grouping of GLIs by GLM compliance.

Step 3. Selection of criteria system and formation of a set of multi-criteria models for GLM and GLI ranking.

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We propose to use estimates of logistic flow parameters (Figure 4) as a system of criteria. This choice is based on the ultimate influence of instruments on these parameters, as a result of which the achievement of the SDGs is ensured. A detailed description of the selected two-level criteria system is presented in [32,39]. The set of multi-criteria models includes one GLM ranking model for the entire supply chain and six GLI ranking models, one for each logistics element.

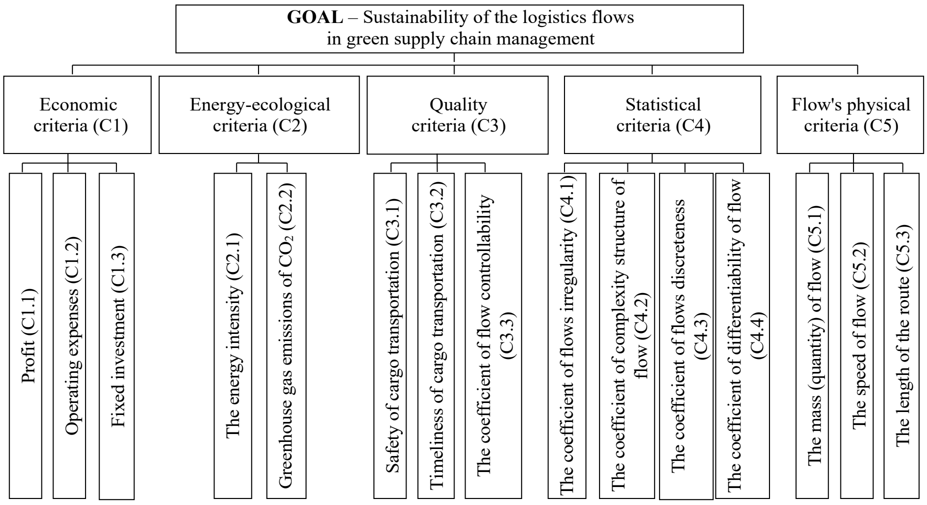

Figure 4. Logistic flow evaluation system [39].

Step 4. Formation of an expert group, preparation of questionnaires for GLM and GLI assessment using a system of criteria. The expert group should include representatives of the academic community, as well as businesses in the field of logistics and supply chain management. It is desirable that the experts' qualifications allow them to adequately assess the importance of methods and instrumentss for different elements of the supply chain.

Step 5. Calculation of weights of criteria for evaluation of green logistics methods and instruments. Since impacts on different parameters of logistics flows using GLM and GLI have different impacts on the achievement of SDGs, it is necessary to calculate the weights of criteria for assessing logistics flows. The most common methods for calculating criteria weights in green supply chains are AHP, ANP, BWM, CRITIC, DEMATEL, FUCOM and others [38]. The input data for calculations using these methods are expert estimates of criteria weights. Multiple scales can be used to improve the accuracy of the estimation, for example with fuzzy, rough and gray numbers.

Step 6. Obtaining expert evaluations of alternatives. Assessment can be done using a variety of scales. Formation of initial decision-making matrices for ranking methods (1) and instruments (2) considering the criteria weights. The initial matrices in general form have the following.

$$X_{met} = \begin{array}{c} \\ \\ M_1 \\ M_2 \\ \vdots \\ M_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \\ w_1 & w_2 & \cdots & w_n \end{array} \\ \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \end{array}, \qquad (1)$$

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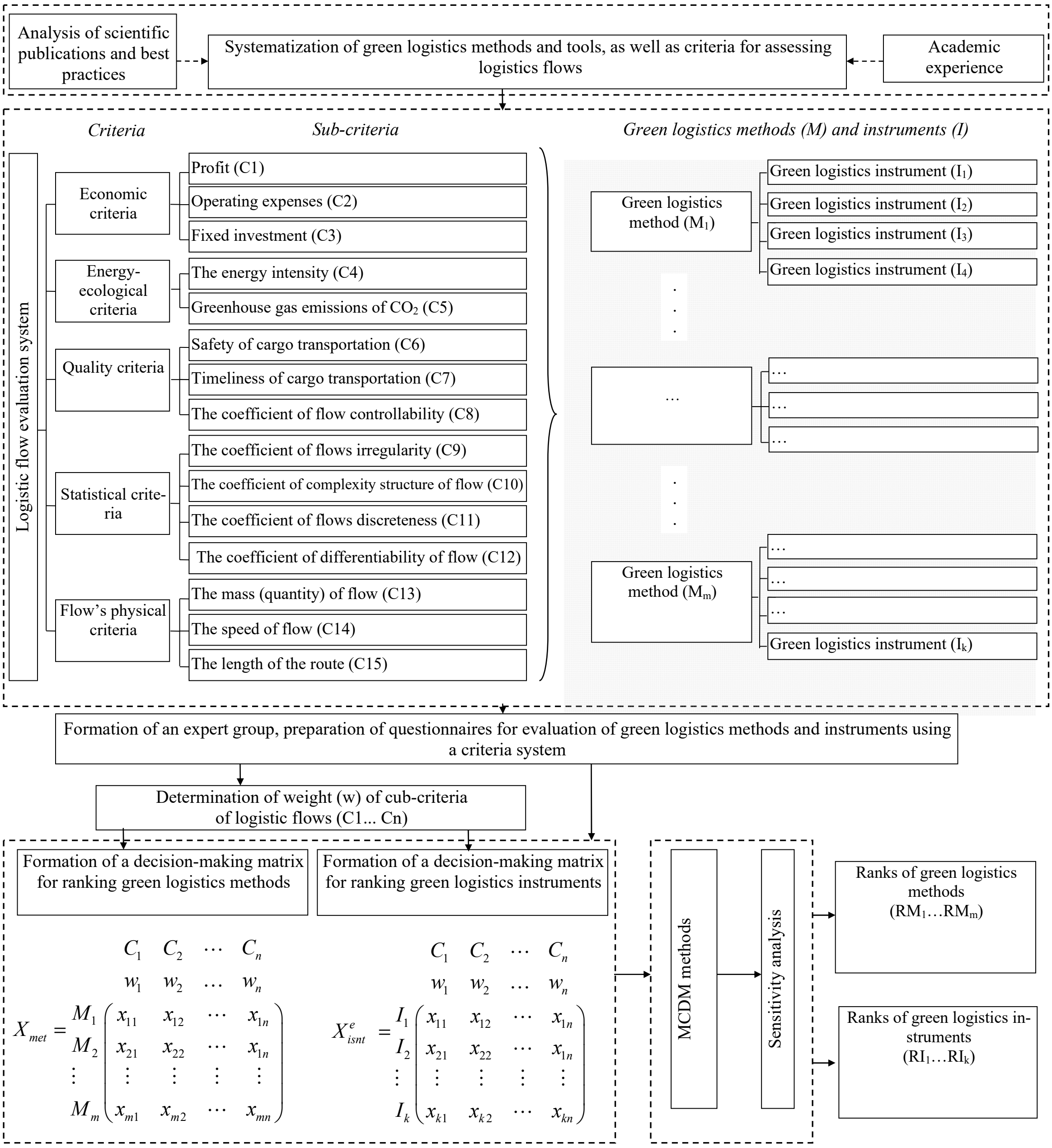
$$X_{inst} = \begin{array}{cc} & \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \\ w_1 & w_2 & \dots & w_n \end{array} \\ \begin{array}{c} I_1 \\ I_2 \\ \vdots \\ I_k \end{array} & \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{k1} & x_{k2} & \cdots & x_{kn} \end{pmatrix} \end{array}, \qquad (2)$$

where $M = \{M_1, M_2 \ldots M_m\}$ – green logistics methods; m – number of methods; $I = \{I_1, I_2 \ldots I_k\}$ – green logistics instruments; k – number of instruments; $C = \{C_1, C_2 \ldots C_n\}$ – criteria of logistics flows; n – number of criteria; $w = \{w_1, w_2 \ldots w_n\}$ – weight of criteria; x_{ij} or x_{gj} – respectively the evaluation value of i – method and g – instruments according to j – criterion C.

Step 7. Multi-criteria ranking of green logistics methods and instruments using MCDM. The selection of a specific MCDM is necessary in this step. MCDMs differ in their data aggregation methods and algorithms, accuracy of results, and computational labor intensity. Common methods for ranking green supply chain solutions are SAW, TOPSIS, PROMETHEE, COPRAS, ARAS, WASPAS, EDAS, MABAC, CODAS, MARCOS, etc. [37].

Step 8: Sensitivity analysis of the ranking results. The results obtained using one of the selected MCDMs are compared with those calculated by other multi-criteria methods. The ranked GLMs and GLIs are used by decision makers to align sustainability programs and projects across all elements of the supply chain.

The multi-criteria assessment framework for GLM and GLI is presented in Figure 5. The criteria system (Figure 4) is shown as an example on this framework.



$$
X_{met} = \begin{array}{c|cccc} & C_1 & C_2 & \cdots & C_n \\ & w_1 & w_2 & \cdots & w_n \\ M_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ M_2 & x_{21} & x_{22} & \cdots & x_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ M_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{array}
\qquad
X^{e}_{isnt} = \begin{array}{c|cccc} & C_1 & C_2 & \cdots & C_n \\ & w_1 & w_2 & \cdots & w_n \\ I_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ I_2 & x_{21} & x_{22} & \cdots & x_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ I_k & x_{k1} & x_{k2} & \cdots & x_{kn} \end{array}
$$

Figure 5. The multi-criteria assessment framework for GLM and GLI.

4. Case Study

This section presents an example of ranking green logistics methods and instruments. In the first step, we analyzed 184 research papers on the use of various green solutions and practices in supply chains. The identified green solutions and practices are grouped according to the supporting functions of green supply chain elements. The results of the research analysis are presented in Table 2.

Table 2. Grouping of scientific papers in relation to logistic elements and by mention of Green Logistics Methods (M) and Instruments (I).

Element	GLM (GLI)	References
Control element	$M_{1.1}$ – Environmental management ($I_{1.1.1}$ - $I_{1.1.4}$)	[2,4,5,12,17,19–21,23,25,28,30,31,40–168]
	$M_{1.2}$ – Development and implementation of corporate information systems ($I_{1.2.1}$ - $I_{1.2.6}$)	[2,4,13,18,21,30,31,42,43,48,58,60,65,68–74,79,

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Element	GLM (GLI)	References
		82,88,90,98,102,108,112,116,117,119,127,135, 137,141,166,167,169–173]
	$M_{1.3}$ – Selection of systems for identification and positioning of rolling stock and cargo ($I_{1.3.1}$ - $I_{1.3.3}$)	[5,18,21,54,82,136,141,143,169,171,174]
	$M_{1.4}$ – Development and implementation of intelligent transport system ($I_{1.4.1}$ - $I_{1.4.4}$)	[31,60,61,70–73,77,79,82,90,102,116,118,127, 128, 134,152,169,172,175]
	$M_{1.5}$ – Development and implementation of information and communication technologies ($I_{1.5.1}$ - $I_{1.5.4}$)	[2,5,19,21,30,31,46,49,50,52,54,59–61,63,65, 68,69,71–73,75,79,82,84,86,87,89,91,95,101–104, 114,115,117–120,122,124,128,131–133,135, 136,138,141,143,160,166,168,169,174,176–181]
Input element	$M_{2.1}$ – Suppliers market research ($I_{2.1.1}$ - $I_{2.1.4}$)	[4,17,20–22,30,31,40,42,43,49,52–54,57,59,60,62, 63,65,66,68,69,72,83,84,92,93,95,96,98,101,106, 114–116,124,127,131,138,140,142,147,154, 155,158,162,165,167,168,171,182–190]
	$M_{2.2}$ – Ecologically acceptable raw materials, containers and packaging ($I_{2.2.1}$ - $I_{2.2.3}$)	[4,5,20,21,30,42,45,49,50,52–54,56,57,62,65–67, 69,75,76,81,86,87,89,92,93,96,97,100,101,103, 105,107,109,119,120,126,134,139,140,142,143, 147,149,152–154,156,163–165,167,168,171,184, 186,188,189]
	$M_{2.3}$ – The selection of suppliers ($I_{2.3.1}$ - $I_{2.3.2}$)	[2,4,5,12,17,20,21,25,28,30,31,40–42,45,48,49, 51–53,58,59,62,63,66,69,73,74,76,78,79,82,83, 87,91–97,101,103,105,113,115,116,118,119,124, 126,127,130,136,138–140,142–144,147,148,150, 151,154,156–158,160–165,167,168,171,176,179, 181,183,184,186,187,191–194]
	$M_{2.4}$ – Procurement planning, execution and supply controlling ($I_{2.4.1}$ - $I_{2.4.5}$)	[17,20,21,30,42,43,52–54,57,61,63,73,89,94, 96,108,117,120,123,132,140–143,149,153,171, 174,193]
Processing	$M_{3.1}$ – The use of ecologically acceptable raw materials ($I_{3.1.1}$ - $I_{3.1.3}$)	[4,5,20,21,28,30,40–42,45,46,48–50,52,54–59,

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Element	GLM (GLI)	References
element		65–67,73,75,76,81,84,89,92,97–100,105,108,109, 119,124,126,129,134,140,142,143,147,149,152, 153,156,162–164,167,168,171,184,188–192,194]
	$M_{3.2}$ – The use of environmentally sound equipment and technologies ($I_{3.2.1}$ - $I_{3.2.4}$)	[5,12,18–23,25,28,30,31,41–43,45,46,48,50, 52–59,64,65,67,70,73,75,76,78,79,81,84,90, 92–95,98–101,105,106,108,109,111,113,121, 122,124,126,127,129,134,135,137,138,140,142, 143,145–148,150,151,156,160–165,167,169, 171,179,181,182,184,186,192,195–197]
	$M_{3.3}$ – Industrial waste management (reverse logistics) ($I_{3.3.1}$ - $I_{3.3.3}$)	[2,5,12,18–23,25,28,30,42,45,46,49,50,52–55, 57–59,66,69,70,74–76,78,80,83,87,89,93–95,97, 98,100,105,106,108,113,114,119–122,126,134, 137,138,140,141,143,145,147,148,150,152–154, 156,157,161–165,167,178,179,182,184,188,189, 193–195]
	$M_{3.4}$ – Technological flows management ($I_{3.4.1}$ - $I_{3.4.3}$)	[4,20–22,25,28,30,40–42,44,45,50,51,57–62,64, 66,67,69,70,73,75,78,82,83,89,90,92,95,97–99, 101,103–109,111,113,115,117,119,121,122, 124,126,129,130,137,138,140,142,144–152,154, 156–158,161–164,168,171,179,182,184, 186,189,192–194]
	$M_{3.5}$ – Work with staff ($I_{3.5.1}$ - $I_{3.5.4}$)	[4,5,18–21,28,30,40,42,48–50,54–57,59,63–65, 67–69,71–74,79–88,91,93–95,98–101,103,104, 107,108,110,112,116,118,119,122,124,125, 127–129,135–138,142,143,147,149,153,160,161, 165,195]
Cumulative element	$M_{4.1}$ – Environmental design of warehouse complexes ($I_{4.1.1}$ - $I_{4.1.6}$)	[12,13,19,21–23,30,31,41,54,57,59,67,75,80, 84,89,93,106,113,123,126,135,136,140–143, 149,150,156,160,161,165,168,171,175,176,189,

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Element	GLM (GLI)	References
		197–199]
	$M_{4.2}$ – Use of environmentally acceptable handling equipment's and vehicles ($I_{4.2.1}$ - $I_{4.2.2}$)	[5,12,13,21,23,30,31,41,42,45,50,52,54,57,58,73, 75,90,92,94,98,109,113,124,127,134,135,141, 145,148,156,159,163–165,167,171,183,186,193, 195,197,199]
	$M_{4.3}$ – Loading/unloading and warehouse operations ($I_{4.3.1}$ - $I_{4.3.5}$)	[2,4,5,18–21,30,41,42,49–52,54,57,59,60,62,66, 75,76,86,87,89,92,96,101,105,106,116,119,126, 129,136,140–143,145,150,152,154,156,159–163, 165,167,168,171,172,183–186,188,190,194–199]
	$M_{4.4}$ – Material flows management ($I_{4.4.1}$ - $I_{4.4.4}$)	[2,5,12,14,17,18,20–22,30,42,48,50,52,54,57, 60,61,65,80,82,84,89,101,115,117,126,127,141, 147,160,161,170–173,179,182,183,186,190, 194,195]
Transport element	$M_{5.1}$ – Selection of cargo delivery scheme ($I_{5.1.1}$ - $I_{5.1.3}$)	[5,12,19–21,23,30,41,46,49,54,57,65,75,77,79, 101,106,115,126,134,136,140–142,156,159–161, 166–168,171,176,178,181,184,189,192–194,196, 198,200]
	$M_{5.2}$ – Selection of environmentally friendly vehicles ($I_{5.2.1}$ - $I_{5.2.4}$)	[5,18–20,23,30,41,46,52,54,57,73,76,77,92,115, 126,134,136,141–143,156,160,165–167,171,176, 177,180,181,183,184,196,200,201]
	$M_{5.3}$ – Transport management and transport planning ($I_{5.3.1}$ - $I_{5.3.7}$)	[14,18–20,41,52,54,59,75,77,126,136,141–143, 160,165–168,171,173,174,176–178,180,181, 196,200]
	$M_{5.4}$ – Material flows management ($I_{5.4.1}$ - $I_{5.4.4}$)	[17,20,52,54,61,65,75,80,82,108,117,120,122,123, 129,141,147,166,171,177,181,190,194]
Output element	$M_{6.1}$ – Marketing analyses of distribution ($I_{6.1.1}$ - $I_{6.1.3}$)	[4,5,14,17,20–22,30,40–42,45,49,50,52,54, 57,58,61,64,68,71,75,78,82–87,91,92,94,100, 105–107,109,110,114,116,118,120,124–126,130, 135,137,138,140,142,143,146,153,155–159, 161–165,179,187,192,193,202]

Element	GLM (GLI)	References
	$M_{6.2}$ – Management of packing and packaging (reverse logistics) ($I_{6.2.1}$ - $I_{6.2.4}$)	[2,4,5,19–21,30,41,42,46,49–52,54,57,59,60, 62,66,74–76,78,86,87,89,92,101,105,106,119, 126,129,136,140–143,145,150,152,154,156, 159–163,165,167,168,171,175,176,183–186, 188,192,194–196,198,202]
	$M_{6.3}$ – Selection of distribution channels ($I_{6.3.1}$ - $I_{6.3.4}$)	[4,14,17,19–22,30,40,42,45,46,48–50,52,54,57, 59,62,73,75,76,78,82,86,101,110,116,120,126, 136,139,141,146,147,150,160,162,170,171,173, 174,177,178,183,184,187,193,194,197,202]
	$M_{6.4}$ – Work with consumers of products and services ($I_{6.4.1}$ - $I_{6.4.3}$)	[4,5,17,20,21,30,42,50,52,54,57,62,71,73, 74,78, 82–87,89,94,101,105,107,114,118,120,124, 126,130,132,135,138,140,153,155,156,158,161, 163,164,174,179,192]
	$M_{6.5}$ – Management technology of return and reverse material flows ($I_{6.5.1}$ - $I_{6.5.4}$)	[2,5,12,17,20–23,40,42,43,49,50,52,54,55,57–59, 66,74–76,78,89,92,95,97,100,114,120,124,126, 129,140,142,143,147,148,150,151,154,157,162, 163,167,168,171,173,182–184,187–189,191, 194–196,202,203]

Figures 6–11 shows the results of systematization of green logistics methods and instruments separately for each logistic element. The corresponding elements are highlighted in color. A detailed description of each green logistics instrument is given in Tables 3–8. The names of the instruments are close to the formulations of traditional logistics support functions and tasks. However, from the perspective of green logistics, they should be considered as methods and instruments for achieving sustainable development goals. These goals are indicated in the figures by the corresponding well-known pictograms [204].

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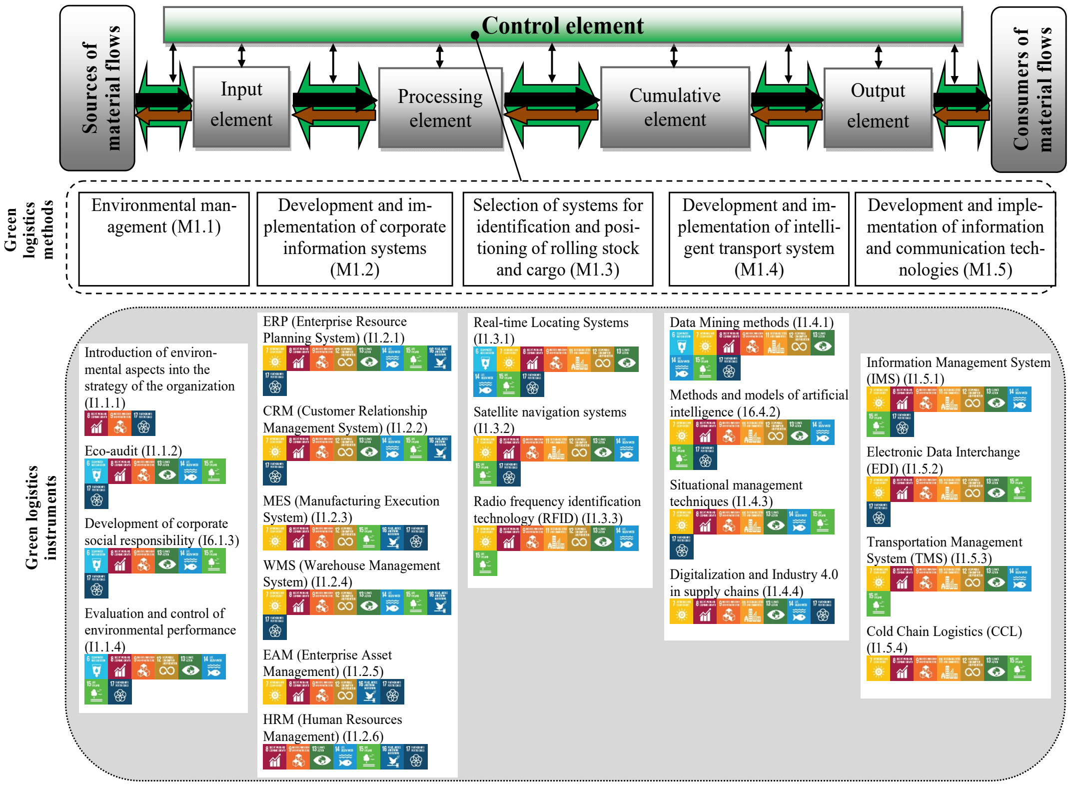

Figure 6. Geen logistics methods and instruments for the Control Logistics Element.

Table 3. Description of green logistics instruments for the Control Logistics Element.

№	Green logistics instrument	Description
I1.1.1	1.1. Introduction of environmental aspects into the strategy of the organization	Development of the organization's environmental strategy based on the goals and principles of sustainable development and its integration into the business strategy (ESG-strategy)
I1.1.2	1.2. Eco-audit	Independent assessment of compliance with regulatory and legal requirements in the field of environmental protection and preparation of recommendations in the field of environmental activities
I1.1.3	1.3. Development of corporate social responsibility	Design and implementation of the strategy for developing the concept of Corporate Social Responsibility (CSR), taking responsibility for external and internal stakeholders, the environment, and society as a whole
I1.1.4	1.4. Evaluation and control of environmental performance	Design standards for the process of selecting indicators, collecting and evaluating data and information to provide an ongoing assessment of environmental performance and its trends over time, consistent with the organization's environmental goals (ISO 14031:2013)
I1.2.1	Enterprise Resource Planning System (ERP)	Implementation of the enterprise resource management and planning system based on the integration and automation of data required to perform business processes — production, financial, personnel management, service provision, etc.
I1.2.2	Customer Relationship Management System (CRM)	Implementation of Customer Relationship Management (CRM) based on the use of advanced management and information technologies to interact with customers to

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№	Green logistics instrument	Description
		increase the efficiency of customer service and improve business processes
I1.2.3	Manufacturing Execution System (MES)	Implementation of Manufacturing Execution System (MES) based on data integration and automation to manage manufacturing activities
I1.2.4	Warehouse Management System (WMS)	Implementation of Warehouse Management System (WMS) based on data integration and automation for planning and execution of a set of tasks and functions of warehouse business processes
I1.2.5	Enterprise Asset Management (EAM)	Implementation of Enterprise Asset Management (EAM) based on automation of business processes for managing physical assets and their modes of operation, risks, and costs throughout the asset lifecycle
I1.2.6	Human Resources Management (HRM)	Implementation of Human Resources Management (HRM) based on the integration of data required to effectively manage the organization's workforce
I1.3.1	Real-time Locating Systems (RTLS)	Implementation of Real-time Locating Systems (RTLS) based on the use of methods and technologies of identification and location of controlled objects (UWB, RFID, Wi-Fi, Bluetooth, ZigBee, NFER, etc.) within the territory for the purpose of monitoring transportation, logistics and business processes
I1.3.2	Satellite navigation systems	Implementation of satellite navigation systems (GPS, GLONAS, BeiDou, Galileo, QZSS and IRNSS) to determine the location of objects and movement parameters (vehicles, cargoes, etc.) to monitor the performance of logistics functions and supply chain operations
I1.3.3	Radio frequency identification technology (RFID)	Implementation of Radio Frequency Identification (RFID) technology in transportation and logistics processes for automatic identification, transmission, and storage of information about elements of the material flow throughout the life cycle from production to retail trade
I1.4.1	Data Mining methods	Use of Data Mining methods and systems for intellectual analysis of the data array and identification of patterns for the purpose of making managerial decisions (Board, SAS Revenue Optimization, SAS Enterprise Miner, etc.).
I1.4.2	Methods and models of artificial intelligence	Integration of systems, technologies or intelligent machines capable of mimicking human behavior in performing logistics functions in the supply chain
I1.4.3	Situational management techniques	The use of a set of techniques and methods of managerial decision-making in the operational management of supply chains under the influence of external and internal changes. This set includes system, situational and factor analysis, expert methods, simulation modeling, multi-criteria decision-making methods, heuristic methods and others
I1.4.4	Digitalization and Industry 4.0 in supply chains	Control and optimization of logistics flows based on the implementation of principles and technologies of Industry 4.0 concept and digitalization of supply chains (cloud technologies, Internet of Things, blockchain, artificial intelligence and machine learning, virtual reality, 3D printing, etc.)
I1.5.1	Management Information System (MIS)	Implementation of Management Information System (MIS) for decision-making, coordination, control, analysis, and

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№	Green logistics instrument	Description
		visualization of information in supply chains by integrating the links between chain members, processes, and technologies required to perform business processes
I1.5.2	Electronic Data Interchange (EDI)	Implementation of Electronic Data Interchange (EDI) transfer of structured digital information between organizations – elements of the supply chain, based on regulations and formats of transmitted messages.
I1.5.3	Transportation Management System (TMS)	Implementation of the Transportation Management System (TSM) for complex automation of transportation and logistics operations
I1.5.4	Cold Chain Logistics (CCL)	Utilizing Cold Chain Logistics (CCL) technologies and techniques to ensure consistent temperature of goods in the supply chain from production to consumption

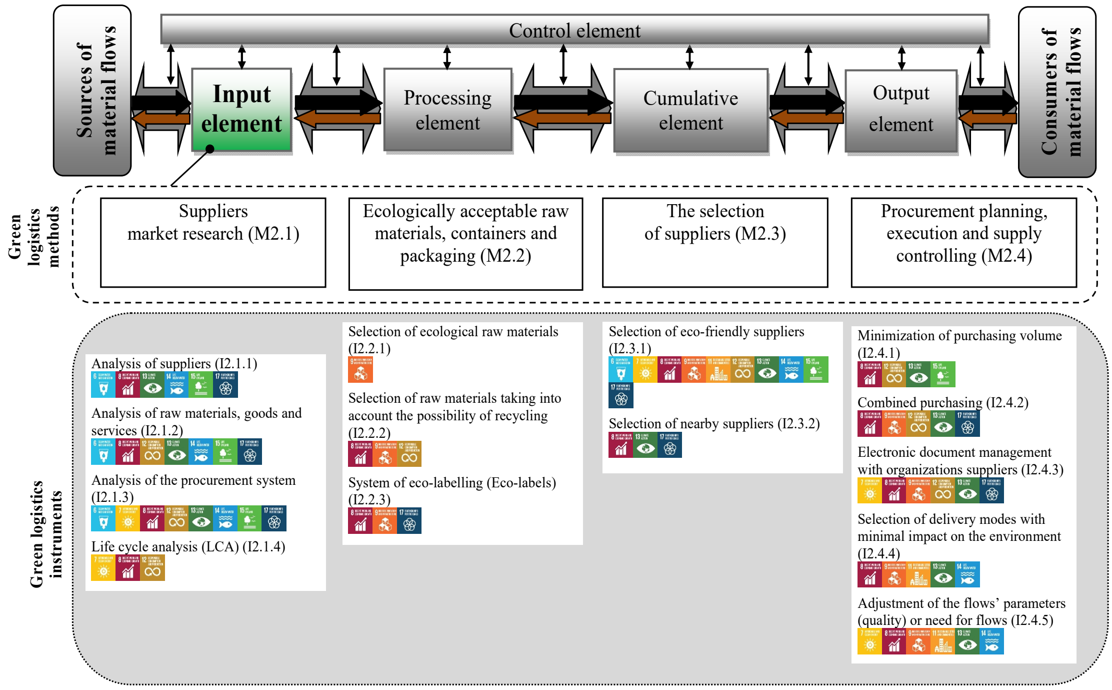

Figure 7. Green logistics methods and instruments for the Input Logistics Element.

Table 4. Description of green logistics instruments for the Input Logistics Element.

№	Green logistics instrument	Description
I2.1.1	Analysis of suppliers	Assessment of suppliers' and contractors' performance for the purpose of further cooperation by analyzing previous activities, as well as compliance with the requirements and principles of the customer's work, including in achieving SDGs
I2.1.2	Analysis of raw materials, goods and services	Assessing products and services for compliance with customer and supply chain requirements
I2.1.3	Analysis of the procurement system	Evaluate the management of logistics processes in procurement to effectively utilize logistics resources and achieve the SDGs
I2.1.4	Life cycle analysis (LCA)	Comprehensive assessment of the environmental impact of a logistics material or work flow at all stages of its life cycle

№	Green logistics instrument	Description
I2.2.1	Selection of ecological raw materials	Selection of environmentally friendly and safe raw materials in logistics processes, ensuring the least impact on the environment and human health
I2.2.2	Selection of raw materials taking into account the possibility of recycling	Selection of raw materials and materials considering the possibility of their reuse and recycling
I2.2.3	System of eco-labelling (eco-labels)	Use of eco-labeling system to identify products and services for compliance with environmental standards and requirements, inform consumers about environmental properties of products or services
I2.3.1	Selection of eco-friendly suppliers	Evaluate and select suppliers that have environmental policies and incorporate environmentally friendly mechanisms into their operations
I2.3.2	Selection of nearby suppliers	Assessing and selecting the nearest suppliers to reduce logistics costs and environmental impact
I2.4.1	Minimization of purchasing volume	Analysis of cargo flow parameters and optimization of purchasing volumes to minimize inventories and reduce logistics costs
I2.4.2	Combined purchasing	Consolidation of procurement and collective tendering to reduce logistics costs and environmental footprints
I2.4.3	Electronic document management with organizations suppliers	Implementation of the electronic document management system and refusal to use paper carriers
I2.4.4	Selection of delivery modes with minimal impact on the environment	Assessing and selecting methods of raw material delivery with minimal environmental impact
I2.4.5	Adjustment of the flows' parameters (quality) or need for flows	Analysis of statistical parameters of logistics flows to assess the need for them, as well as to optimize their parameters and indicators

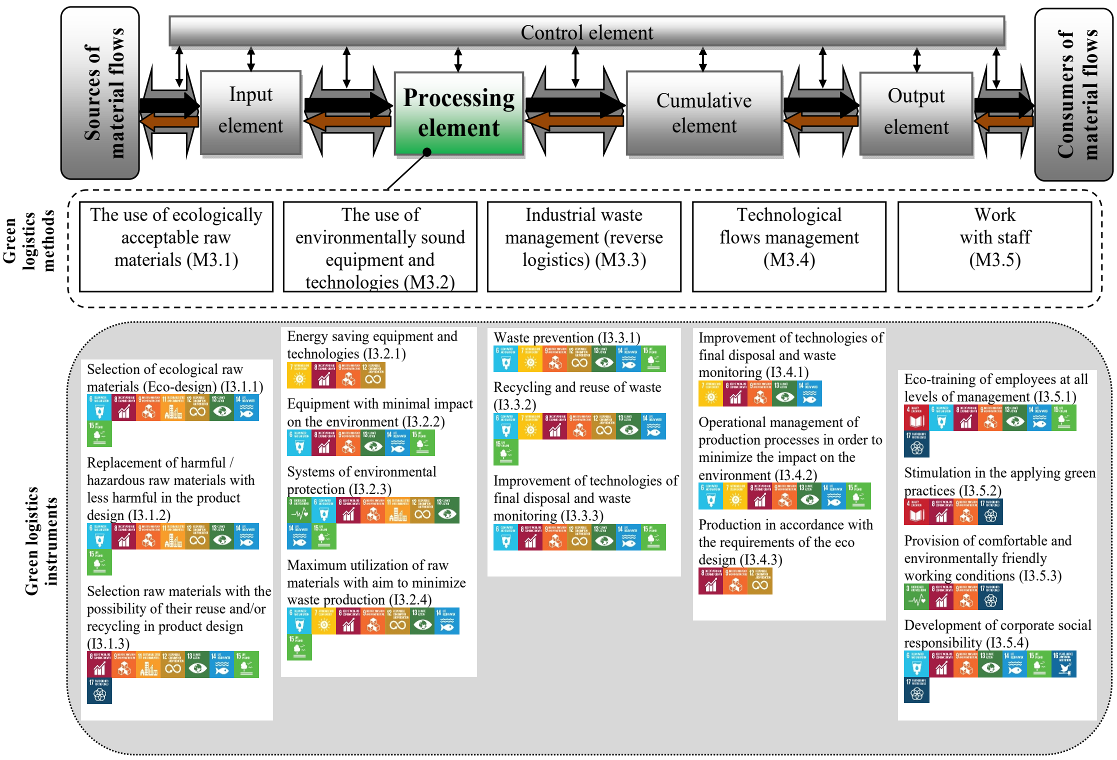

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Figure 8. Green logistics methods and instruments for the Processing Logistics Element.

Table 5. Description of green logistics instruments for the Processing Logistics Element.

№	Green logistics instrument	Description
I3.1.1	Selection of ecological raw materials (Eco-design)	Consideration of environmental parameters in the process of creating products (services) when selecting raw materials and materials used in production processes to improve the natural, social, cultural and physical environment of certain areas
I3.1.2	Replacement of harmful/hazardous raw materials with less harmful in the product design	Replacing harmful and hazardous raw materials in the process of creating products (services) with environmentally friendly ones that ensure the least impact on the environment and human health
I3.1.3	Selection raw materials with the possibility of their reuse and/or recycling in product design	Considering the possibility of reusing and recycling raw materials in the process of creating products (services)
I3.2.1	Energy saving equipment and technologies	Application of energy-saving equipment and resource-saving technologies to rationally utilize logistics resources and improve production efficiency
I3.2.2	Equipment with minimal impact on the environment	Selection and application of equipment and technologies with minimal environmental impact in production processes
I3.2.3	Systems of environmental protection	Use of environmental safety methods and technical systems (air protection systems, water protection systems, waste management systems, etc.) to reduce the negative impact on the environment
I3.2.4	Maximum utilization of raw materials with aim to minimize waste production	Analysis of production process parameters and implementation of methods that maximize the use of raw material components to minimize production and service waste
I3.3.1	Waste prevention	Selection and application of ways to prevent waste generation in the process of production of products (services)
I3.3.2	Recycling and reuse of waste	Selection and application of waste treatment methods to ensure its reuse in logistics processes and to obtain raw materials, energy, products, and supplies
I3.3.3	Improvement of technologies of final disposal and waste monitoring	Evaluate and select ways to control and improve technologies for the utilization of waste generated during production, operation and after decommissioning
I3.4.1	Optimization of technological flows' parameters	Analyzing the parameters of production processes and operations and making decisions to adjust the parameters of industrial logistics flows to reduce logistics costs and achieve the SDGs
I3.4.2	Operational management of production processes in order to minimize the impact on the environment	Operational management of production processes to control product quality and reduce the negative environmental impact of the industry
I3.4.3	Production in accordance with the requirements of the eco design	Designing and manufacturing products and services with consideration of their environmental impact throughout their life cycle

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№	Green logistics instrument	Description
I3.5.1	Eco-training of employees at all levels of management	Training in the field of environmental protection and ecological safety for managers and specialists responsible for decision-making in the implementation of activities that have a negative impact on the environment
I3.5.2	Stimulation in the applying green practices	Stimulating supply chain participants' activities and personnel behavior in implementing "green" principles and technologies to reduce the negative impact on the environment
I3.5.3	Provision of comfortable and environmentally friendly working conditions	Creation of favorable conditions of the production environment and labor process, which have an impact on personnel health, working capacity and labor productivity, labor satisfaction, efficiency, and safety of work
I3.5.4	Development of corporate social responsibility	Incentivizing personnel in implementing the CSR strategy

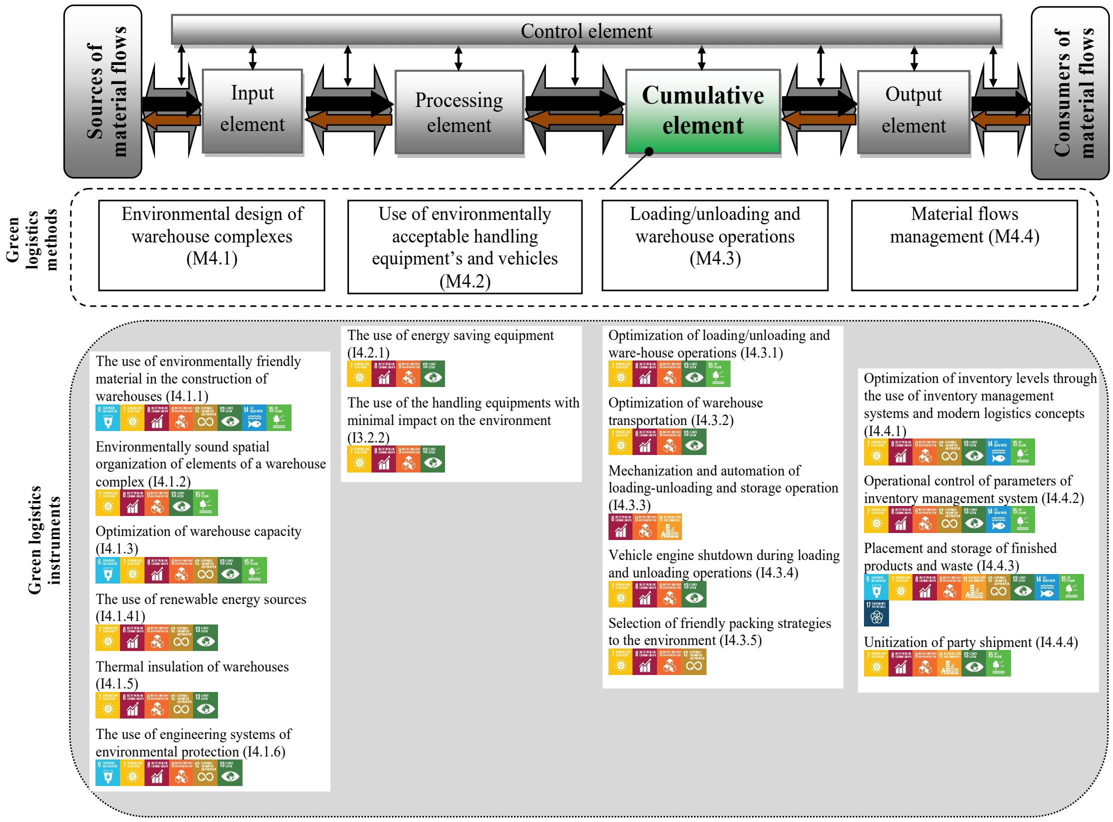

Figure 9. Green logistics methods and instruments for the Cumulative Logistics Element.

Table 6. Description of green logistics instruments for the Cumulative Logistics Element.

№	Green logistics instrument	Description
I4.1.1	The use of environmentally friendly material in the construction of warehouses	The use of modern environmentally friendly and safe building materials and technologies in the construction of warehouses in accordance with ISO 14024:1999, LEED, BREEAM, DGNB, Green Globes, CASBEE, BEAM and other standards
I4.1.2	Environmentally sound spatial organization of	Warehouse design, warehouse space planning and placement of main elements considering the requirements

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№	Green logistics instrument	Description
	elements of a warehouse complex	of environmental standards and the use of modern safety equipment, as well as the efficiency of loading and unloading and storage operations
I4.1.3	Optimization of warehouse capacity	Analysis of statistical parameters of cargo flows to optimize warehouse capacity and ensure the quality of inventory storage
I4.1.4	The use of renewable energy sources	Utilization of renewable energy sources in the warehouse to reduce greenhouse gas emissions (bioenergy, photovoltaics, concentrated solar energy, geothermal energy, hydropower, ocean energy, wind energy)
I4.1.5	Thermal insulation of warehouses	Use of special materials and technologies to insulate warehouses to ensure comfortable working conditions for the personnel and reduce the costs of heating the warehouse
I4.1.6	The use of engineering systems of environmental protection	Use of autonomous and centralized engineering systems ensuring maintenance of specified environmental parameters (air conditioning systems, ventilation systems, heating systems, water environment protection systems, energy saving systems, physical security systems, etc.)
I4.2.1	The use of energy saving equipment	Application of energy-saving equipment and resource-saving technologies to rationally utilize logistics resources and improve warehouse efficiency
I4.2.2	The use of the handling equipment's with minimal impact on the environment	Use of loading and unloading means and devices with minimal environmental impact in the warehouse
I4.3.1	Optimization of loading/unloading and warehouse operations	Regulating the parameters of loading, unloading and warehousing processes to reduce logistics costs and achieve the SDGs
I4.3.2	Optimization of warehouse transportation	Use of progressive organization of cargo movement between different storage areas in the warehouse to minimize transshipment and optimize intro-warehouse routes
I4.3.3	Mechanization and automation of loading-unloading and storage operation	Mechanization and automation of loading and unloading and warehousing operations to reduce the share of manual processes and operations and increase labor productivity in warehousing operations
I4.3.4	Vehicle engine shutdown during loading and unloading operations	Disabling the vehicle engine during loading and unloading operations to reduce fuel consumption and CO_2 emissions
I4.3.5	Selection of friendly packing strategies to the environment	Developing and using a packaging strategy to prevent damage and loss of goods, efficiently utilize resources, and reduce environmental impact (ISO 18601-06: 2013)
I4.4.1	Optimization of inventory levels through the use of inventory management systems and modern logistics concepts	Optimization of inventory levels based on the Inventory Management Systems and modern logistics concepts (Just-in-Time, Kanban, Lean Production, etc.)
I4.4.2	Operational control of parameters of inventory management system	Operational control of deviations of the actual parameters of the inventory management system from the optimal ones and decision-making to regulate these parameters
I4.4.3	Placement and storage of finished products and waste	Optimal filling of storage space, safe and efficient handling and warehousing services

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№	Green logistics instrument	Description
I4.4.4	Unitization of party shipment	Consolidation of cargo consignments for efficient use of vehicles, reduction of transportation expenses and harmful emissions into the environment

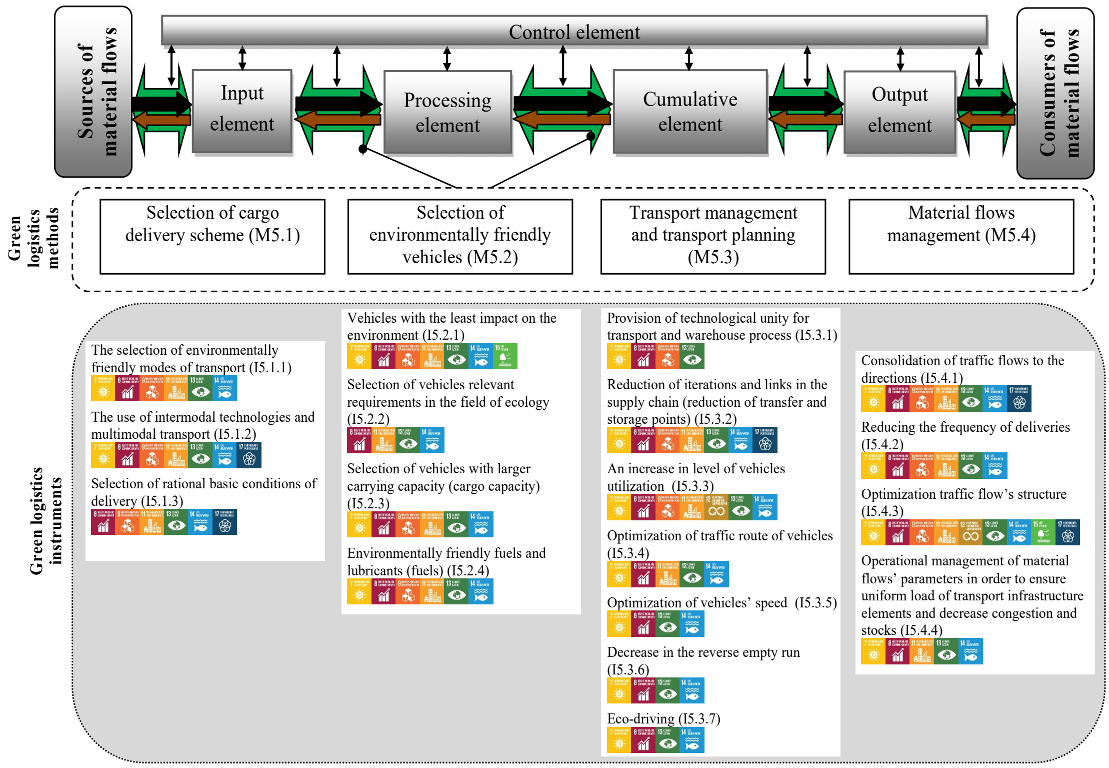

Figure 10. Green logistics methods and instruments for the Transport Logistics Element.

Table 7. Description of green logistics instruments for the Transport Logistics Element.

№	Green logistics instrument	Description
I5.1.1	The selection of environmentally friendly modes of transport	Assessment and selection of transport modes and transport planning systems for efficient transport of goods and reduction of negative environmental impacts
I5.1.2	The use of intermodal technologies and multimodal transport	Use in supply chains of multimodal delivery systems with intermodal technologies based on sequential or parallel advancement of cargo flows by several modes of transportation, and elimination of transshipment operations when transferring cargo from one mode of transportation to another
I5.1.3	Selection of rational basic conditions of delivery	Selection of basic terms of delivery of goods that define the duties, place of transfer of goods, cost, and risks arising in the delivery of goods from sellers to buyers, considering the least negative impact on the environment
I5.2.1	Vehicles with the least impact on the environment	Selection and use of vehicles with the least negative environmental impact throughout the life cycle, including zero emission vehicles — ZEVs
I5.2.2	Selection of vehicles relevant requirements in the field of ecology	Evaluating and selecting vehicles that comply with established environmental regulations and requirements (Euro 1-6)

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№	Green logistics instrument	Description
I5.2.3	Selection of vehicles with larger carrying capacity (cargo capacity)	Selecting a vehicle with a larger payload (cargo capacity) to increase productivity and reduce CO_2 emissions
I5.2.4	Environmentally friendly fuels and lubricants (fuels)	Selection and use of fuels, lubricants and special fluids with improved environmental properties, ensuring reliability and efficiency of vehicle operation
I5.3.1	Provision of technological unity for transport and warehouse process	Ensuring the technological unity of the transportation and warehousing process by unifying the parameters of vehicles, tare, loading and unloading means and devices, places of cargo storage in the warehouse
I5.3.2	Reduction of iterations and links in the supply chain (reduction of transfer and storage points)	Minimize iterations and links in the supply chain (transshipment and storage points) to reduce logistics costs
I5.3.3	An increase in level of vehicles utilization	Selection of the best ways to load vehicles to optimize the use of vehicle load capacity
I5.3.4	Optimization of traffic route of vehicles movement	Optimization of vehicle routes to reduce mileage, fuel consumption, save engine life, and reduce pollutant emissions
I5.3.5	Optimization of vehicles' speed	Selecting vehicle speeds that reduce fuel consumption, emissions, and safety
I5.3.6	Decrease in the reverse empty run	Reducing empty vehicle miles traveled to improve vehicle efficiency, reduce fuel consumption and carbon dioxide emissions
I5.3.7	Eco-driving	Training drivers in vehicle driving techniques that optimize fuel consumption, reduce emissions and improve safety
I5.4.1	Consolidation of traffic flows to the directions	Consolidation of small jets of material flow (cargo flow) into a powerful jet to increase the efficiency of its transportation using the system of main modes of transportation
I5.4.2	Reducing the frequency of deliveries	Optimization of the frequency and size of deliveries based on the inventory management strategy adopted within the boundaries of a particular logistics system
I5.4.3	Optimization traffic flow's structure	Changing the structure of material flow (cargo flow) during transportation, considering the needs of supply chain elements in material flow
I5.4.4	Operational management of material flows' parameters in order to ensure uniform load of transport infrastructure elements and decrease congestion and stocks	Use of various methods of continuous assessment of material flow parameters and their correction in case of deviation from normative values

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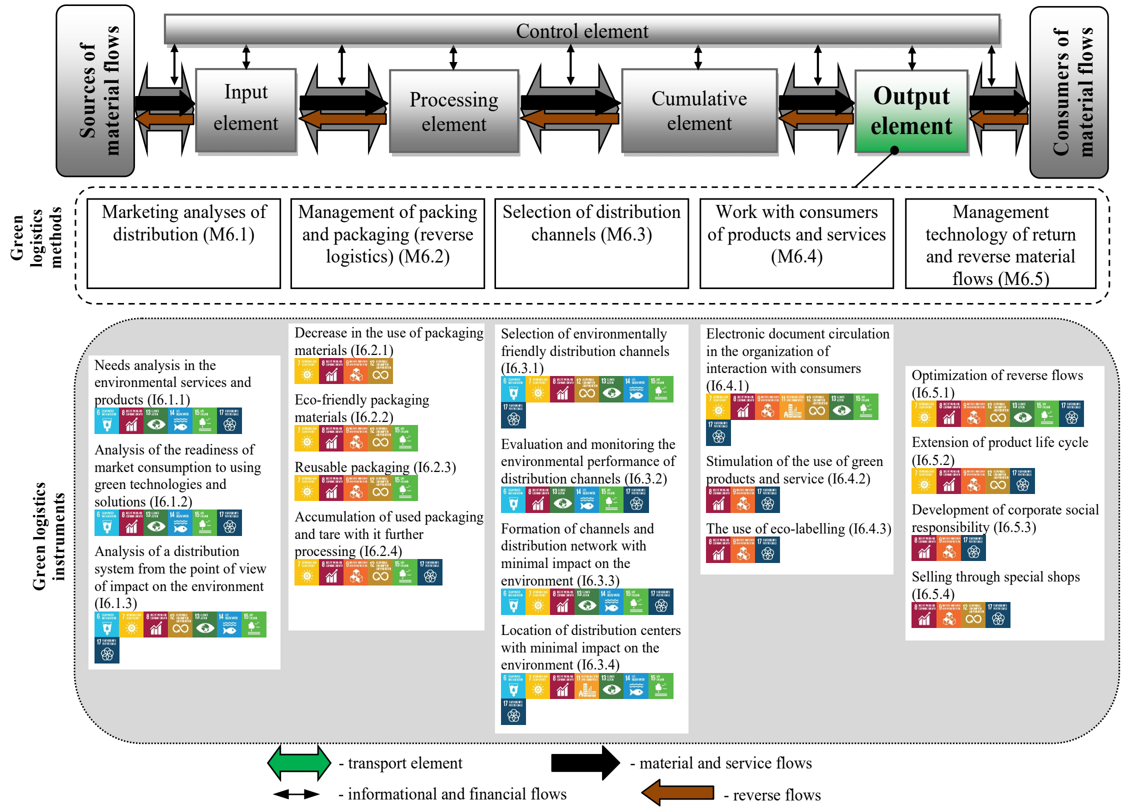

Figure 11. Green logistics methods and instruments for the Output Logistics Element.

Table 8. Description of green logistics instruments for the Output Logistics Element.

№	Green logistics instrument	Description
I6.1.1	Needs analysis in the environmental services and products	Using the principles and methods of green marketing to study the market, demand for goods (services), consumer behavior and competitors to meet consumer demand for environmentally friendly products and services
I6.1.2	Analysis of the readiness of market consumption to using green technologies and solutions	Utilizing a range of different activities to communicate the merits of "green" goods or services to potential consumers and stimulate the consumption of "green" goods or services
I6.1.3	Analysis of a distribution system from the point of view of impact on the environment	Assessment of the distributional system for compliance with the principles of building sustainable supply chains and achieving the SDGs
I6.2.1	Decrease in the use of packaging materials	Rational use of packaging to reduce logistics costs and packaging material volumes
I6.2.2	Eco-friendly packaging materials	Use of eco-friendly packaging materials composed of natural ingredients, as well as materials with ingredients that accelerate their decomposition
I6.2.3	Reusable packaging	Use of reusable and reusable containers and packaging to reduce waste and packaging procurement costs, and to improve the security of cargo delivery
I6.2.4	Accumulation of used packaging and tare with it further processing	Collection of used containers and packaging for recycling by own forces or under contract with specialized organizations

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№	Green logistics instrument	Description
I6.3.1	Selection of environmentally friendly distribution channels	Assessment and selection of distribution channels that implement environmental policies and incorporate environmentally friendly mechanisms in their operations
I6.3.2	Evaluation and monitoring the environmental performance of distribution channels	Operational elimination of the distributional system parameters deviations from those set in accordance with the SDGs or ESG strategy
I6.3.3	Formation of channels and distribution network with minimal impact on the environment	Use of strategy and methods for the formation of the distribution network with minimal environmental impact
I6.3.4	Location of distribution center's with minimal impact on the environment	Green field analysis for distribution centers to reduce logistics costs and reduce negative environmental impact
I6.4.1	Electronic document circulation in the organization of interaction with consumers	Using the system and EDI operator to organize work with documents by forming them electronically, without using paper carriers
I6.4.2	Stimulation of the use of green products and service	Stimulating consumers of products or services whose behavior is based on the concepts of sustainable development, responsible, ethical, "green" consumption
I6.4.3	The use of eco-labelling	Use of eco-labeling system to inform consumers about the environmental properties of products or services
I6.5.1	Optimization of reverse flows	Use of methods of handling return material flows, i.e., reuse, recycling, utilization of goods, materials, and wastes
I6.5.2	Extension of product life cycle	Extension of product life cycle based on the use of principles and methods of closed-loop economy and Closed-loop Supply Chain, including defect elimination, repair, restoration, refurbishment, modernization of products
I6.5.3	Development of corporate social responsibility	Cooperation with various charitable, environmental, volunteer organizations, animal shelters, etc. for donation of products
I6.5.4	Selling through special shops	Sale of goods and services through specialized stores, including Zero waste stores, online stores, second hand stores, eco-markets, food sharing, etc.

Seven MCDM models are formed to rank green logistics methods and instruments.

1. Supply chain model (27 methods — M1.1-M6.5).
2. Control element model (21 instruments — I1.1.1-I1.5.4).
3. Input element model (14 instruments — I2.1.1-I2.4.5).
4. Processing element model (17 instruments — I3.1.1-I3.5.4).
5. Cumulative element model (17 instruments — I4.1.1-I4.4.4).
6. Transport element model (18 instruments — I5.1.1-I5.4.4).
7. Output element model (18 instruments — I6.1.1-I6.5.4).

A system of 15 logistics flow criteria is used to evaluate green logistics methods and instruments. The weight values of the criteria of logistic flows are taken from [205]. Fuzzy Analytic Hierarchy Process (Fuzzy AHP) is used to evaluate the weight of criteria.

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Table 9. Weight of logistic flows' criteria and sub-criteria [205].

Criteria	Weight	Sub criteria	Weight	Global weight
Economic criteria (C1)	0.2538	C1.1	0.75726	0.19216
		C1.2	0.01508	0.00383
		C1.3	0.22766	0.05777
Energy-ecological criteria (C2)	0.2220	C2.1	0.98622	0.21890
		C2.2	0.01378	0.00306
Quality criteria (C3)	0.2474	C3.1	0.44784	0.11080
		C3.2	0.30491	0.07544
		C3.3	0.24725	0.06117
Statistical criteria (C4)	0.0005	C4.1	0.41160	0.00020
		C4.2	0.32903	0.00016
		C4.3	0.17474	0.00009
		C4.4	0.08463	0.00004
Flow’s physical criteria (C5)	0.2764	C1.1	0.45068	0.12456
		C2.2	0.54476	0.15056
		C3.3	0.00456	0.00126

A group of five academic experts in the field of Supply chain management, transport systems, Logistics was formed to perform the assessment. The average length of service of the experts is 25.4 years. The experts evaluated the impact of green logistics methods and instruments on logistics flow criteria on a five-point scale: 1 – very low, 2 — low, 3 — medium, 4 — high, 5 — very high. The results of expert assessments are presented in Tables 10.

Table 10. Results of expert assessment of green logistics methods and instruments.

Element	GLM / GLI	C11	C12	C13	C21	C22	C31	C32	C33	C41	C42	C43	C44	C51	C52	C53
Control element	M1.1	2.35	2.93	2.17	3.03	3.90	1.64	1.52	1.78	1.32	1.15	1.15	1.32	1.64	1.43	1.64
	I1.1.1	3.064	3.245	2.297	3.776	4.129	2.825	3.178	3.519	2.352	2.221	2.297	2.297	1.516	2.551	3.366
	I1.1.2	2.169	2.000	1.741	2.930	3.519	2.702	2.702	2.993	2.491	2.551	2.702	2.702	1.516	2.352	2.048
	I1.1.3	2.993	3.519	3.594	3.245	4.317	2.825	2.825	3.519	2.702	2.930	2.862	2.862	2.169	3.104	3.438
	I1.1.4	2.702	2.862	3.981	3.594	4.317	2.605	2.825	3.641	2.862	3.031	2.639	2.639	1.644	2.862	4.076
	M1.2	3.52	3.25	3.73	3.10	2.49	2.83	3.52	3.98	3.44	2.70	2.55	2.70	2.70	3.37	1.89
	I1.2.1	2.825	3.288	2.169	2.551	2.930	2.048	2.702	2.605	2.352	2.048	2.048	2.048	1.644	2.460	1.783
	I1.2.2	2.551	2.639	2.352	2.702	2.491	2.352	3.565	3.807	2.352	2.551	2.048	1.888	1.516	3.129	1.888
	I1.2.3	2.169	2.702	1.741	2.352	3.245	1.149	1.320	1.783	1.320	1.320	1.320	1.320	1.888	1.783	1.644
	I1.2.4	1.888	2.169	1.888	2.048	3.680	1.644	1.516	1.516	1.320	1.320	1.320	1.320	1.644	1.888	1.516
	I1.2.5	2.862	3.565	2.352	3.641	3.438	2.169	1.516	2.702	2.352	2.605	1.888	2.000	2.639	2.048	2.605
	I1.2.6	3.519	3.728	2.639	3.807	4.129	1.516	1.320	2.221	2.268	2.402	1.974	2.091	2.993	1.783	2.268
	M1.3	2.70	3.10	3.90	2.40	2.17	3.13	3.59	3.59	3.29	2.22	2.30	2.17	1.52	3.10	1.74
	I1.3.1	2.825	3.104	2.551	3.438	3.594	2.000	1.320	2.766	1.974	2.091	1.974	2.091	2.402	1.783	1.974
	I1.3.2	1.888	2.048	1.149	1.741	1.888	1.149	1.149	1.741	1.320	1.516	1.431	1.516	2.000	1.644	2.169
	I1.3.3	2.766	2.702	1.888	1.516	2.048	1.888	1.516	2.221	1.644	2.491	2.048	2.169	2.048	1.888	2.491
	M1.4	3.73	3.68	4.13	3.73	3.29	3.73	4.13	4.32	3.59	3.13	3.17	3.17	2.35	4.32	3.73
	I1.4.1	2.352	2.930	2.169	3.031	3.898	1.644	1.516	1.783	1.320	1.149	1.149	1.320	1.644	1.431	1.644

Element	GLM / GLI	C11	C12	C13	C21	C22	C31	C32	C33	C41	C42	C43	C44	C51	C52	C53
	I1.4.2	2.352	2.297	2.141	3.031	3.807	1.644	1.516	1.933	1.320	1.246	1.149	1.320	1.783	1.552	1.888
	I1.4.3	2.048	2.766	1.644	2.639	3.594	1.644	1.516	1.888	1.320	1.149	1.149	1.320	1.644	1.431	1.644
	I1.4.4	2.352	2.352	1.320	2.169	2.930	1.888	1.741	1.644	1.516	1.431	1.431	1.431	1.149	1.149	1.149
	M1.5	3.44	3.73	4.08	3.29	3.29	3.52	3.73	3.76	3.59	3.44	3.03	3.03	2.55	3.90	2.86
	I1.5.1	2.460	2.402	2.268	2.491	2.993	2.091	1.821	1.974	1.741	1.431	1.431	1.431	1.320	1.320	1.149
	I1.5.2	3.519	3.245	3.728	3.104	2.491	2.825	3.519	3.981	3.438	2.702	2.551	2.702	2.702	3.366	1.888
	I1.5.3	3.519	2.993	3.438	2.825	2.551	2.825	3.323	4.317	3.438	3.064	2.551	2.551	2.402	2.491	1.888
	I1.5.4	2.930	2.702	3.438	2.402	2.352	2.352	2.702	4.317	3.438	2.551	2.352	2.352	2.000	2.702	2.169
Input element	M2.1	3.59	3.39	3.32	2.05	2.49	1.78	2.64	2.55	2.77	2.86	2.77	2.22	2.99	2.49	2.83
	I2.1.1	3.807	3.438	2.491	2.993	2.000	2.605	3.807	2.551	3.366	2.862	3.178	2.551	2.352	2.639	3.245
	I2.1.2	4.129	3.898	2.702	2.605	2.169	2.000	2.048	2.352	2.702	2.551	2.862	2.169	2.759	2.268	2.491
	I2.1.3	3.680	3.898	3.170	2.862	1.888	2.048	2.221	3.104	2.825	2.993	3.245	2.221	2.702	2.702	2.491
	I2.1.4	3.064	2.930	2.862	2.702	2.169	1.431	1.888	2.352	2.169	2.000	2.352	1.783	2.491	2.993	2.091
	M2.2	3.10	4.00	2.35	2.70	4.13	1.64	1.32	1.64	1.52	2.70	2.49	2.49	2.55	2.35	2.14
	I2.2.1	3.104	4.000	1.783	2.702	3.758	1.000	1.000	1.149	1.149	2.702	2.048	2.639	2.169	1.888	2.759
	I2.2.2	3.807	4.317	2.048	3.594	4.317	1.516	1.516	1.431	1.320	2.702	2.169	2.491	3.288	2.551	2.724
	I2.2.3	2.048	2.551	1.888	2.000	1.821	1.888	1.431	1.516	1.431	1.933	1.320	1.320	1.320	1.431	1.552
	M2.3	3.29	3.37	2.17	2.77	3.29	3.48	4.57	3.95	3.44	2.49	2.93	2.77	2.17	2.61	4.13
	I2.3.1	2.551	2.702	1.741	2.221	3.641	2.352	2.402	2.091	1.888	2.221	2.048	2.169	1.644	2.169	4.183
	I2.3.2	3.898	4.317	1.741	3.519	3.129	3.565	4.317	4.183	3.807	2.862	3.366	3.000	2.169	2.759	4.782
	M2.4	4.13	4.37	2.41	3.29	3.10	3.90	4.32	4.32	4.13	3.37	3.57	3.57	2.86	3.10	2.86
	I2.4.1	4.317	4.573	2.862	3.680	3.482	3.104	2.702	3.288	2.825	2.862	2.408	2.551	4.782	3.064	2.221
	I2.4.2	3.129	4.129	2.352	3.245	3.245	2.930	3.288	3.776	3.728	4.076	3.565	3.594	3.565	2.862	2.993
	I2.4.3	2.491	3.104	2.352	2.352	2.702	2.551	2.862	4.076	2.993	2.169	1.888	2.048	1.516	2.667	1.431
	I2.4.4	3.245	3.438	2.825	3.366	5.000	2.551	2.862	2.048	2.825	2.993	2.605	2.605	2.297	2.491	3.728
	I2.4.5	3.438	3.728	2.000	3.104	3.482	2.352	2.639	4.129	4.129	4.129	3.366	3.064	3.104	3.565	2.169
Processing element	M3.1	3.39	4.13	2.55	3.31	4.08	1.43	1.32	1.32	1.74	2.83	2.22	2.22	3.03	1.78	2.17
	I3.1.1	3.393	4.573	2.605	3.466	3.314	1.380	1.149	1.149	1.516	2.352	1.933	2.048	2.048	2.169	1.888
	I3.1.2	2.993	3.949	2.766	3.170	3.898	1.516	1.320	1.149	1.516	2.825	2.352	2.221	2.862	1.888	1.888
	I3.1.3	3.129	4.317	2.352	3.393	4.317	1.149	1.320	1.320	1.644	2.221	2.048	2.048	2.759	2.048	2.268
	M3.2	3.10	3.57	3.98	3.59	4.78	1.74	1.74	1.78	1.89	1.78	1.78	1.64	2.35	2.22	2.05
	I3.2.1	3.288	3.949	3.981	3.981	4.317	1.516	1.516	1.431	1.644	1.516	1.431	1.644	2.491	2.169	2.048
	I3.2.2	2.862	3.178	3.981	3.594	5.000	1.149	1.320	1.320	1.320	1.431	1.320	1.320	1.516	1.888	1.888
	I3.2.3	2.551	3.178	3.641	3.393	4.514	1.516	1.149	1.644	1.516	1.320	1.149	1.516	1.644	1.741	1.741
	I3.2.4	4.076	4.076	2.491	3.594	4.129	1.431	1.644	2.169	2.169	2.460	2.460	1.888	3.178	2.169	2.169
	M3.3	3.68	3.90	3.18	3.44	4.08	1.15	1.32	2.55	2.22	2.70	2.22	2.70	3.29	2.49	2.76
	I3.3.1	2.993	3.641	2.091	3.314	3.758	1.149	1.320	2.048	2.352	2.352	2.221	2.221	2.605	1.644	1.974
	I3.3.2	3.898	3.898	2.352	3.641	4.317	1.149	1.516	2.702	2.702	3.064	2.221	2.491	3.594	2.169	2.993
	I3.3.3	2.702	3.949	3.438	3.807	4.317	1.149	1.320	1.888	2.048	2.169	2.221	2.169	2.491	2.352	1.888
	M3.4	3.52	4.13	2.27	3.39	3.13	1.89	2.70	3.64	3.03	2.99	2.64	3.03	3.37	3.44	2.86
	I3.4.1	3.314	3.519	2.169	3.104	3.245	1.888	2.825	3.641	3.170	2.605	2.639	2.639	3.728	3.170	3.170
	I3.4.2	2.702	3.519	1.585	3.594	3.594	1.644	1.552	2.862	2.862	2.221	2.048	2.408	2.297	2.000	2.297
	I3.4.3	2.825	3.519	2.460	3.129	3.807	1.149	1.149	1.149	1.149	1.516	1.320	1.644	1.644	1.320	1.516

Element	GLM / GLI	C11	C12	C13	C21	C22	C31	C32	C33	C41	C42	C43	C44	C51	C52	C53
Cumulative element	M3.5	3.25	4.00	1.89	3.06	3.17	1.43	1.55	2.05	1.52	1.64	1.52	1.64	1.52	1.78	1.32
	I3.5.1	2.702	3.565	1.320	2.825	3.129	1.320	1.320	2.000	1.741	1.516	1.516	1.644	1.516	1.644	1.320
	I3.5.2	2.702	3.366	1.149	3.245	3.728	1.644	1.741	2.169	2.048	2.000	1.888	1.888	1.644	1.644	1.431
	I3.5.3	2.352	3.949	2.825	3.104	2.862	1.516	1.516	1.783	1.783	1.741	1.644	1.644	1.516	1.516	1.516
	I3.5.4	2.352	3.366	1.320	2.297	2.169	2.297	2.297	2.000	1.741	1.431	1.320	1.320	1.320	1.320	1.320
	M4.1	2.49	3.95	4.57	3.81	3.39	2.27	2.05	2.09	2.00	1.89	1.78	1.64	2.35	2.35	1.78
	I4.1.1	2.491	3.949	4.573	3.807	3.393	2.268	2.048	2.091	2.000	1.888	1.783	1.644	2.352	2.352	1.783
	I4.1.2	1.741	3.104	4.373	2.724	2.091	1.149	1.149	1.000	1.000	1.000	1.000	1.000	1.149	1.000	1.000
	I4.1.3	1.741	2.702	4.076	2.460	2.825	1.431	1.741	1.741	1.516	1.516	1.516	1.516	2.169	2.491	1.821
	I4.1.4	2.930	2.930	3.758	2.702	2.352	2.169	2.605	2.825	2.862	2.825	2.268	2.091	3.129	2.491	1.888
	I4.1.5	3.728	3.728	3.949	3.641	4.782	1.149	1.149	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	I4.1.6	2.491	2.825	3.680	3.949	3.393	3.680	1.320	1.149	1.320	1.149	1.000	1.000	1.149	1.320	1.149
	M4.2	2.64	3.39	4.13	4.18	4.16	1.52	1.43	1.52	1.32	1.43	1.32	1.32	1.43	1.43	1.15
	I4.2.1	2.000	2.825	3.949	3.366	3.949	1.741	1.431	1.741	1.320	1.149	1.000	1.000	1.000	1.000	1.000
	I4.2.2	2.639	3.393	4.129	4.183	4.163	1.516	1.431	1.516	1.320	1.431	1.320	1.320	1.431	1.431	1.149
	M4.3	2.83	3.95	3.44	3.57	3.57	2.99	3.10	3.02	3.59	3.17	2.64	2.17	1.89	3.25	1.32
	I4.3.1	3.519	3.680	4.129	4.373	4.782	1.516	1.320	1.246	1.149	1.000	1.000	1.000	1.246	1.149	1.000
	I4.3.2	2.702	3.245	3.949	3.949	5.000	1.585	1.516	1.320	1.246	1.320	1.149	1.149	1.246	1.246	1.149
	I4.3.3	2.825	3.949	3.438	3.565	3.565	2.993	3.104	3.017	3.594	3.170	2.639	2.169	1.888	3.245	1.320
	I4.3.4	3.519	4.129	2.605	3.519	3.170	3.129	2.759	2.885	2.885	3.170	2.605	2.091	1.821	2.402	1.585
	I4.3.5	2.862	4.129	1.644	2.993	3.104	2.512	2.402	3.129	3.245	2.862	3.031	2.169	2.000	3.245	1.821
	M4.4	3.90	4.13	2.49	3.73	2.99	3.44	4.13	3.98	3.98	4.32	3.81	3.59	3.06	3.98	2.51
	I4.4.1	4.129	4.317	4.373	3.178	3.104	3.129	3.245	3.129	2.993	2.221	2.551	2.221	1.741	3.594	1.821
	I4.4.2	2.702	3.641	1.320	3.776	4.782	1.149	1.246	1.431	1.149	1.246	1.246	1.149	1.149	1.320	1.149
	I4.4.3	2.402	2.667	1.783	2.702	3.641	1.644	1.783	1.888	1.320	1.320	1.320	1.320	1.320	1.320	1.320
	I4.4.4	3.898	4.129	2.491	3.728	2.993	3.438	4.129	3.981	3.981	4.317	3.807	3.594	3.064	3.981	2.512
Transport element	M5.1	3.73	4.13	3.31	4.08	4.13	3.78	3.57	3.73	3.10	3.10	2.93	2.86	1.89	2.99	2.89
	I5.1.1	4.317	3.898	2.402	4.129	3.129	3.438	3.017	3.017	3.017	2.885	2.885	2.605	2.825	2.885	1.821
	I5.1.2	3.758	3.758	1.644	3.366	2.702	3.064	3.129	3.758	2.885	2.885	2.512	2.091	2.268	2.885	1.821
	I5.1.3	2.639	2.862	2.352	2.352	2.297	3.031	2.352	2.048	2.551	2.702	2.408	2.702	2.702	2.297	2.352
	M5.2	2.86	3.25	3.47	4.08	4.57	2.17	2.35	1.89	2.00	1.74	2.00	1.89	1.74	2.35	1.52
	I5.2.1	3.245	3.393	1.431	2.825	2.402	3.519	3.898	3.807	3.641	3.898	3.594	3.393	3.898	3.594	2.268
	I5.2.2	3.728	4.129	3.314	4.076	4.129	3.776	3.565	3.728	3.104	3.104	2.930	2.862	1.888	2.993	2.885
	I5.2.3	3.064	3.064	3.758	4.129	4.514	2.352	2.491	2.169	1.888	2.169	2.000	1.888	1.644	2.048	1.974
	I5.2.4	3.594	4.076	3.104	3.898	3.807	3.245	3.728	3.949	3.438	3.170	2.862	2.639	1.644	3.178	3.728
	M5.3	3.31	3.90	3.13	3.25	3.37	3.17	3.76	3.31	3.31	3.17	3.17	2.89	2.49	3.47	3.47
	I5.3.1	3.129	3.170	2.352	3.031	3.288	3.482	3.366	3.728	2.930	3.288	3.104	2.702	1.741	3.178	3.323
	I5.3.2	2.862	3.245	3.466	4.076	4.573	2.169	2.352	1.888	2.000	1.741	2.000	1.888	1.741	2.352	1.516
	I5.3.3	2.352	2.930	3.314	3.758	4.514	1.644	1.783	1.741	1.741	1.888	1.741	1.516	1.516	2.551	1.644
	I5.3.4	2.352	2.702	2.885	3.314	4.317	1.431	1.644	1.320	1.320	1.431	1.320	1.320	1.149	1.888	1.320
	I5.3.5	3.288	2.993	3.466	4.129	3.898	2.268	1.974	1.644	2.297	2.268	2.169	1.783	2.402	2.460	1.644
	I5.3.6	3.170	3.898	1.644	3.393	3.758	1.149	1.149	1.320	1.149	1.149	1.149	1.149	1.149	1.320	1.149

Element	GLM / GLI	C11	C12	C13	C21	C22	C31	C32	C33	C41	C42	C43	C44	C51	C52	C53
	I5.3.7	3.314	3.898	3.129	3.245	3.366	3.170	3.758	3.314	3.314	3.170	3.170	2.885	2.491	3.466	3.466
	M5.4	3.13	3.64	2.41	3.29	2.86	2.35	3.44	3.90	3.17	3.47	3.31	3.47	3.31	3.47	3.10
	I5.4.1	3.314	3.565	2.605	3.245	2.862	3.898	3.898	3.641	3.641	3.641	3.438	3.245	2.352	3.641	2.702
	I5.4.2	3.314	3.594	2.702	3.519	3.104	2.993	3.898	3.949	3.641	3.641	3.641	3.594	2.352	4.129	4.129
	I5.4.3	3.104	3.594	1.974	3.366	3.104	2.491	2.993	2.268	2.402	2.297	2.297	2.169	3.245	2.759	1.644
	I5.4.4	3.393	3.728	1.888	3.519	3.728	2.825	4.076	3.641	3.641	2.993	3.438	2.954	2.048	4.129	4.782
Output element	M6.1	2.46	2.70	1.55	2.22	1.89	1.32	1.32	2.05	1.78	1.64	1.55	1.43	1.52	1.89	1.74
	I6.1.1	2.352	2.993	1.644	3.178	3.104	2.169	3.565	3.438	2.551	2.000	1.516	1.888	1.320	4.573	1.320
	I6.1.2	2.993	3.898	1.888	3.104	4.183	1.516	2.000	2.605	1.888	1.741	1.431	1.783	2.297	1.974	3.594
	I6.1.3	2.000	2.702	1.644	3.245	3.519	1.516	1.888	2.639	1.888	1.552	1.320	1.320	1.149	2.491	1.246
	M6.2	2.86	3.52	2.17	3.29	3.90	2.99	2.05	2.35	1.89	2.00	1.64	1.74	2.86	1.89	1.43
	I6.2.1	3.129	3.641	2.408	3.288	2.862	2.352	3.438	3.898	3.170	3.466	3.314	3.466	3.314	3.466	3.104
	I6.2.2	2.702	3.594	2.352	3.565	3.245	2.221	3.288	3.898	3.393	3.594	3.393	3.129	3.393	3.807	3.438
	I6.2.3	2.297	3.438	2.221	3.565	2.862	1.888	3.898	3.245	3.758	3.393	3.314	2.352	3.949	3.981	2.169
	I6.2.4	2.702	3.594	2.268	3.031	2.862	2.352	3.288	3.728	2.993	3.949	3.031	3.438	3.064	3.314	1.644
	M6.3	3.59	3.10	2.83	2.99	2.89	2.30	2.99	3.59	3.31	2.86	2.99	2.70	1.97	2.99	3.81
	I6.3.1	3.129	3.680	1.888	3.031	2.993	2.759	3.680	3.898	3.438	3.438	2.993	2.993	3.438	4.317	3.031
	I6.3.2	2.460	2.702	1.552	2.221	1.888	1.320	1.320	2.048	1.783	1.644	1.552	1.431	1.516	1.888	1.741
	I6.3.3	2.048	2.491	1.516	2.048	2.141	1.149	1.149	1.552	1.431	1.552	1.431	1.431	1.644	1.888	1.644
	I6.3.4	1.888	2.169	1.552	2.221	1.933	1.149	1.320	1.552	1.320	1.431	1.431	1.431	1.320	1.516	1.320
	M6.4	2.83	3.29	2.17	2.55	2.93	2.05	2.70	2.61	2.35	2.05	2.05	2.05	1.64	2.46	1.78
	I6.4.1	2.169	2.491	1.320	2.352	2.460	1.516	1.644	1.783	1.431	1.644	1.431	1.431	1.516	1.644	1.320
	I6.4.2	2.862	3.519	2.169	3.288	3.898	2.993	2.048	2.352	1.888	2.000	1.644	1.741	2.862	1.888	1.431
	I6.4.3	3.323	3.323	1.888	3.104	3.898	2.724	2.000	2.551	1.783	1.644	1.516	1.320	3.104	1.888	1.149
	M6.5	2.86	3.57	2.35	3.64	3.44	2.17	1.52	2.70	2.35	2.61	1.89	2.00	2.64	2.05	2.61
	I6.5.1	2.402	2.605	1.741	3.104	3.898	2.605	1.644	1.741	1.644	1.644	1.516	1.516	2.297	1.644	1.149
	I6.5.2	3.438	3.245	1.741	3.438	3.594	3.129	1.741	2.491	2.048	2.169	2.000	1.516	2.930	2.048	1.741
	I6.5.3	3.104	3.949	2.297	3.482	3.898	1.644	1.320	1.783	2.048	2.402	2.169	2.000	2.605	2.048	2.352
	I6.5.4	3.594	3.104	2.825	2.993	2.885	2.297	2.993	3.594	3.314	2.862	2.993	2.702	1.974	2.993	3.807

For ranking green logistics methods and instruments, we used MCDM methods Technique for Order Preference by Similarity area Comparison Ideal Solution (TOPSIS), Multi-Attributive Border Approximation Area Comparison (MABAC) and Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS). These methods are widely used for multi-criteria evaluation of various aspects of sustainable and green supply chains. The main steps of each method can be found in [206–208].

Tables 11–17 and Figures 12–18 present the ranking results. Sensitivity assessment of the ranking results was performed based on the calculation of Spearman rank correlation coefficient. The average correlation coefficient was for MCDM model of green logistics methods – 0.984. For MCDM model of green logistics instruments: Control element – 0.982; Input element – 0.947; Processing element – 0.979; Cumulative element – 0.983; Transport element – 0.974; Output element – 0.980. The values of the coefficients show a high correlation, which indicates the reliability of the results obtained.

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Additionally, we calculated the value of the Mean Relative Error of the Ranking results (*MRER*) for each MCDM model using the following formula/

$$MRER = \frac{\sum_{i=1}^{M}\sum_{l=1}^{L-1}\left(\left|R_{il} - R_{il+1}\right| + \left|R_{iL} - R_{i1}\right|\right)}{M \times L},$$

where R_{il} – rank of the i-th alternative (GLM or GLI), calculated by the l-th method, M – number of alternatives, L – number of ranking methods, $L \geq 3$.

The *MRER* values for GLM were 1.135. The *MRER* values for GLI: Control element — 1.015; Input element — 0.904; Processing element — 0.901; Cumulative element — 0.745; Transport element — 0.814; Output element — 0.851. The calculated *MRER* values show the minimum deviation in the ranks obtained in the evaluation by different methods.

Table 11. Results of ranking green logistics methods by different MCDM.

Green logistics methods	Rank		
	TOPSIS	MABAC	MARCOS
M1.1	25	24	24
M1.2	6	4	5
M1.3	10	6	7
M1.4	5	3	3
M1.5	4	5	4
M2.1	9	7	9
M2.2	18	18	21
M2.3	14	14	15
M2.4	1	1	1
M3.1	19	20	19
M3.2	17	19	18
M3.3	22	22	22
M3.4	3	8	8
M3.5	23	23	25
M4.1	27	27	27
M4.2	26	26	26
M4.3	13	12	12
M4.4	8	9	6
M5.1	21	17	16
M5.2	24	25	23
M5.3	2	2	2
M5.4	7	10	10
M6.1	20	21	20
M6.2	11	13	13
M6.3	15	15	14
M6.4	12	11	11
M6.5	16	16	17

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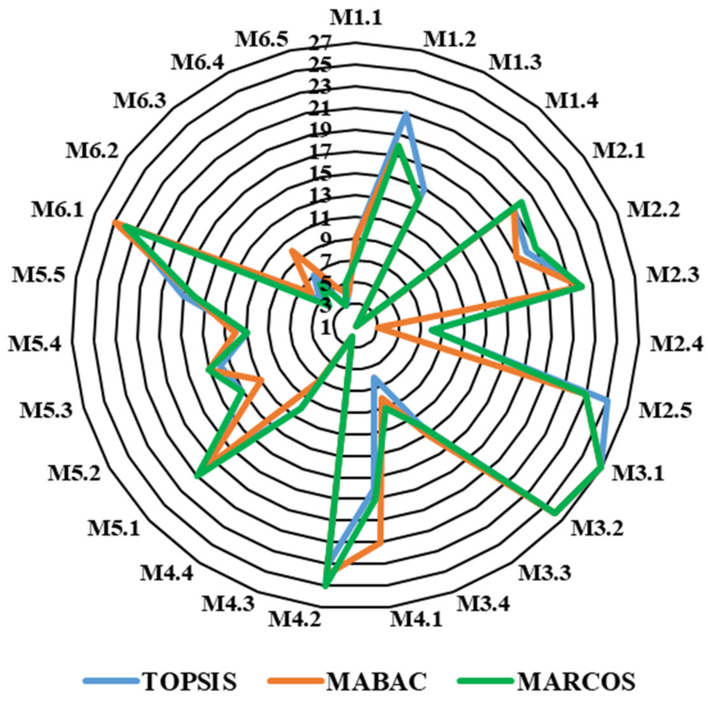

Figure 12. Comparison of ranking results of green logistics methods by TOPSIS, MABAC and MARCOS methods.

Table 12. Ranks of green logistics instruments of the Control element.

Green logistics instrument	Rank		
	TOPSIS	MABAC	MARCOS
I1.1.1	9	9	8
I1.1.2	10	11	12
I1.1.3	4	4	3
I1.1.4	8	7	6
I1.2.1	7	8	9
I1.2.2	5	5	5
I1.2.3	16	17	17
I1.2.4	14	15	14
I1.2.5	13	12	11
I1.2.6	11	10	10
I1.3.1	15	13	13
I1.3.2	12	16	16
I1.3.3	6	6	7
I1.4.1	21	20	20
I1.4.2	20	19	18
I1.4.3	19	21	21
I1.4.4	17	18	19
I1.5.1	18	14	15
I1.5.2	1	1	1
I1.5.3	2	2	2

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I1.5.4	3	3	4

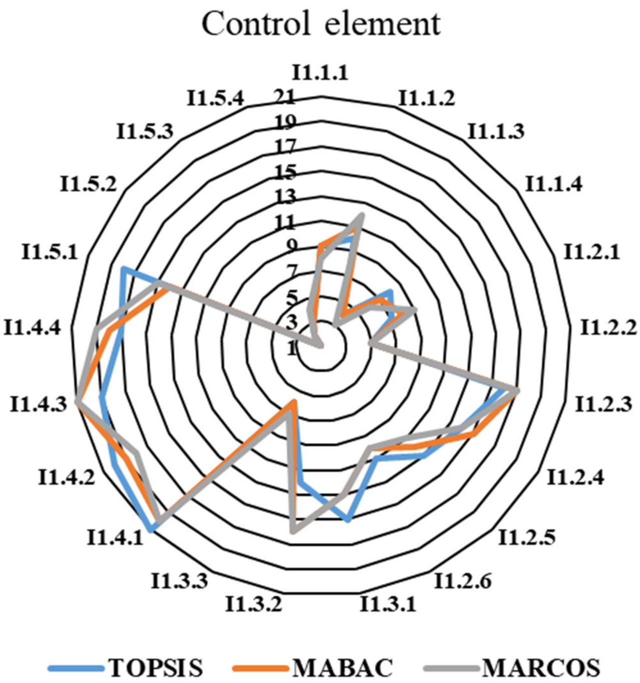

Figure 13. Comparison of ranking results of green logistics instruments for the Control element.

Table 13. Ranks of green logistics instruments of the Input element.

Green logistics instrument	Rank		
	TOPSIS	MABAC	MARCOS
I2.1.1	5	5	5
I2.1.2	6	3	7
I2.1.3	7	4	6
I2.1.4	9	9	9
I2.2.1	14	14	14
I2.2.2	11	12	12
I2.2.3	13	13	13
I2.3.1	12	11	11
I2.3.2	4	6	2
I2.4.1	1	1	1
I2.4.2	2	7	4
I2.4.3	8	8	8
I2.4.4	10	10	10
I2.4.5	3	2	3

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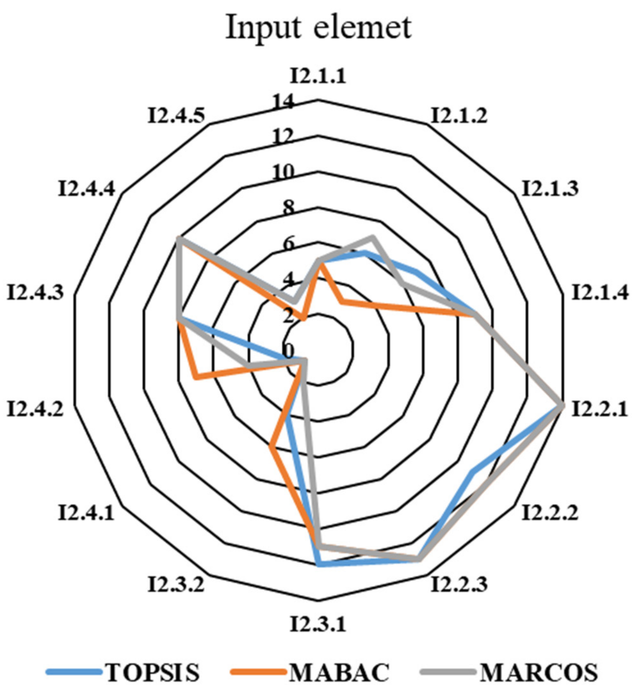

Figure 14. Comparison of ranking results of green logistics instruments for the Input element.

Table 14. Ranks of green logistics instruments of the Processing element.

Green logistics instrument	Rank		
	TOPSIS	MABAC	MARCOS
I3.1.1	9	7	9
I3.1.2	6	5	6
I3.1.3	7	8	7
I3.2.1	4	6	5
I3.2.2	14	16	15
I3.2.3	15	14	13
I3.2.4	2	2	2
I3.3.1	11	10	11
I3.3.2	3	3	3
I3.3.3	8	12	10
I3.4.1	1	1	1
I3.4.2	10	9	8
I3.4.3	17	17	17
I3.5.1	12	13	14
I3.5.2	13	11	12
I3.5.3	16	15	16
I3.5.4	5	4	4

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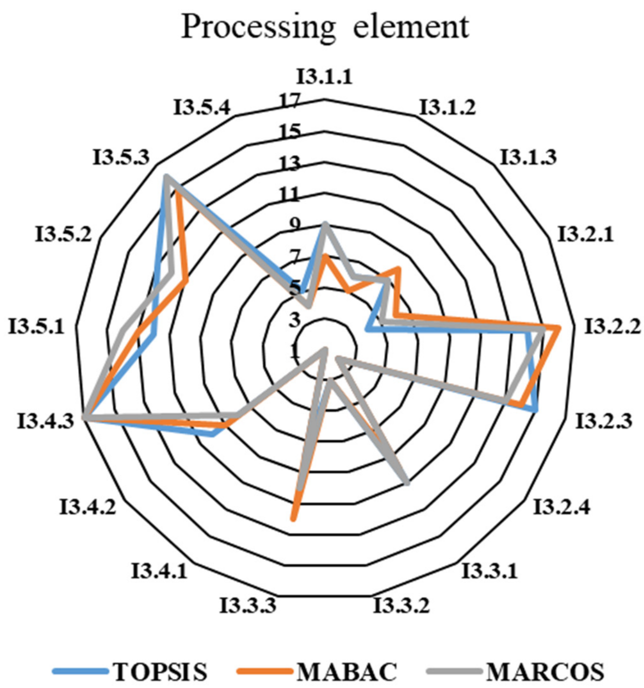

Figure 15. Comparison of ranking results of green logistics instruments for the Processing element.

Table 15. Ranks of green logistics instruments of the Cumulative element.

Green logistics instrument	Rank		
	TOPSIS	MABAC	MARCOS
I4.1.1	7	8	7
I4.1.2	13	12	15
I4.1.3	8	7	8
I4.1.4	3	3	3
I4.1.5	10	11	12
I4.1.6	9	10	10
I4.2.1	16	15	16
I4.2.2	14	16	13
I4.3.1	12	13	11
I4.3.2	15	14	14
I4.3.3	4	5	4
I4.3.4	6	6	6
I4.3.5	5	4	5
I4.4.1	2	2	2
I4.4.2	17	17	17
I4.4.3	11	9	9
I4.4.4	1	1	1

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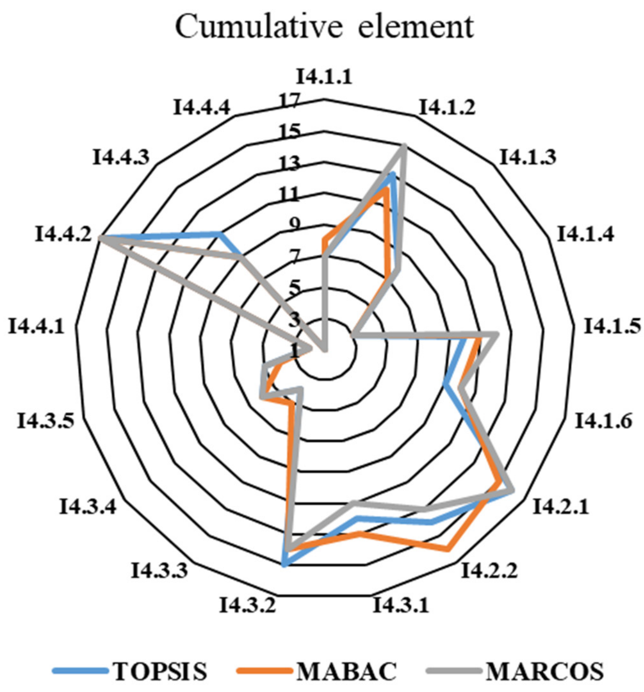

Figure 16. Comparison of ranking results of green logistics instruments for the Cumulative element.

Table 16. Ranks of green logistics instruments of the Transport element.

Green logistics instrument	Rank		
	TOPSIS	MABAC	MARCOS
I5.1.1	5	8	6
I5.1.2	7	7	10
I5.1.3	11	11	11
I5.2.1	1	1	1
I5.2.2	10	9	7
I5.2.3	14	14	14
I5.2.4	12	10	9
I5.3.1	9	6	8
I5.3.2	15	15	15
I5.3.3	16	16	16
I5.3.4	17	17	17
I5.3.5	13	13	13
I5.3.6	18	18	18
I5.3.7	3	3	4
I5.4.1	2	2	2
I5.4.2	4	4	3
I5.4.3	8	12	12
I5.4.4	6	5	5

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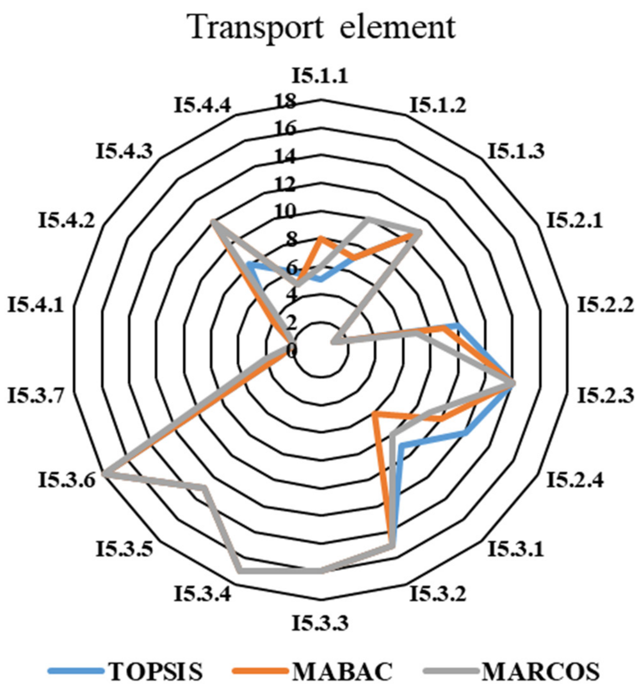

Figure 17. Comparison of ranking results of green logistics instruments for the Transport element.

Table 17. Ranks of green logistics instruments of the Output element.

Green logistics instrument	Rank		
	TOPSIS	MABAC	MARCOS
I6.1.1	7	9	9
I6.1.2	12	11	11
I6.1.3	18	18	17
I6.2.1	2	3	2
I6.2.2	3	5	4
I6.2.3	5	7	6
I6.2.4	4	4	5
I6.3.1	1	1	1
I6.3.2	14	12	14
I6.3.3	15	15	15
I6.3.4	17	17	18
I6.4.1	16	16	16
I6.4.2	10	10	10
I6.4.3	9	6	7
I6.5.1	13	14	13
I6.5.2	8	8	8
I6.5.3	11	13	12
I6.5.4	6	2	3

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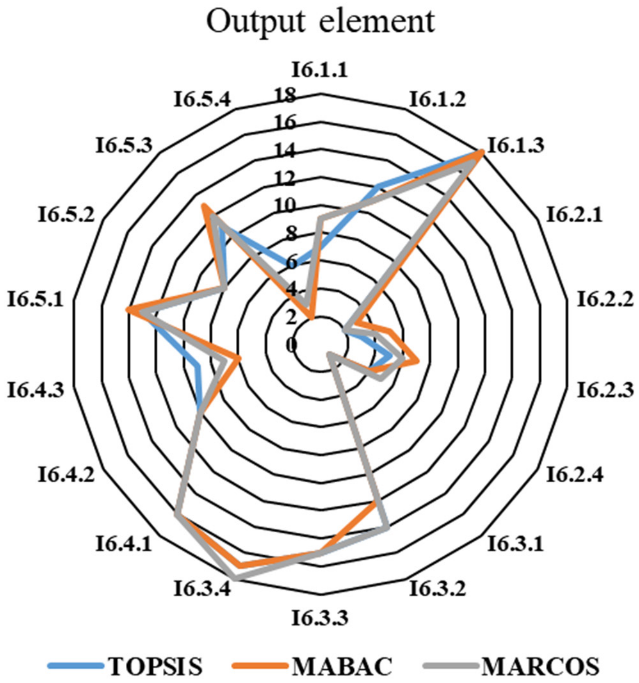

Figure 18. Comparison of ranking results of green logistics instruments for the Output element.

The two most significant green logistics methods are M2.4 Procurement planning, implementation and control (rank #1), M5.3 Transportation management and transportation planning (rank #2). Rank #3 is assigned to two green logistics methods — M1.4 Design and implementation of intelligent transportation system (MABAC, MARCOS assessment) and M3.4 Process flow management (TOPSIS assessment). The three least significant green logistics methods are M4.1 Environmental design of warehouse complexes (rank #27), M4.2 Use of environmentally acceptable handling equipment and vehicles (rank #26). Rank #25 is assigned to three green logistics methods — M1.1 Environmental management (TOPSIS score), M3.5 Human resource management (MARCOS score) and M5.2 Selection of environmentally friendly vehicles (MABAC score).

Ranking the green logistics instruments separately by supply chain elements allowed us to establish the most important instruments (Rank #1): I1.5.2 Electronic data interchange (Control Element), I2.4.1 Minimization of procurement volume (Input Element), I3.4.1 Optimization of process flow parameters (Processing Element), I4.4.4 Unification of batch shipment (Cumulative Element), I5.2.1 Vehicles with the least environmental impact (Transportation Element), I6.3.1 Selection of green distribution channels (Output Element).

Green logistics instruments with the lowest rank: I1.4.1. Data Mining techniques and I1.4.3. Situational management techniques (Control Element), I2.2.1. Selection of environmentally friendly raw materials (Input element), I3.4.3. Production according to eco design requirements (Processing element), I4.4.2. Operational control of inventory management system parameters (Cumulative Element), I5.3.6. Reduction of return empty mileage (Transport Element), I6.1.3. Analysis of the distribution system in terms of environmental impact, and I6.3.4. Location of distribution centers with minimal environmental impact (Output Element).

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5. Conclusions

The methodology of classification and ranking of methods and instruments of green logistics in supply chains is presented. The peculiarity of the proposed approach is the consideration of the supply chain as a universal model of six elements (Control, Input, Processing, Cumulative, Transport, and Output) each of which implements all known functional areas of logistics for the promotion and processing of material flow. Each element performs a set of supporting functions peculiar only to it. To improve the sustainability of the supply chain, the performance of supporting functions by elements should be based on the implementation of methods and instruments of green logistics.

Based on the literature review, the classification of currently existing green solutions and practices by supporting functions of supply chain elements is performed. A universal system of green logistics methods and instruments is proposed, and definitions of each instrument are given. This system includes 27 methods and 105 instruments.

The system of criteria for assessing logistics flows is used as criteria for the effectiveness of the implementation of green logistics methods and instruments. The implementation of green logistics instruments has an impact on the criteria of logistics flows and allows achieving the goals of sustainable development of supply chains. To assess the impact of green logistics methods and instruments on the criteria of logistics flows, it is proposed to use multi-criteria decision-making methods.

Ranking green logistics methods and instruments using MCDM methods was performed. Fuzzy AHP was used to estimate the weight of criteria of logistic flows. TOPSIS, MABAC and MARCOS methods were used to rank the methods and instruments. The ranking results by different MCDM showed high convergence — The average Spearman rank correlation coefficient was 0.975, the value of the Mean Relative Error of the Ranking results was 0.909.

The most significant methods of green logistics are “Procurement planning, execution and supply controlling”, “Transport management and transport planning” “Development and implementation of intelligent transport system” and “Technological flows management”. The most significant instruments of green logistics in the supply chain elements are: “Electronic Data Interchange” (Control element), “Minimization of purchasing volume” (Input element), “Optimization of technological flows’ parameters” (Processing element), “Unitization of party shipment” (Cumulative element), “Vehicles with the least impact on the environment” (Transport element), “Selection of environmentally friendly distribution channels” (Output element).

Thus, we proposed considering the developed system of green logistics methods and instruments as a universal framework for the implementation of management decisions to improve supply chain sustainability. The limitation of this study is the small number of experts involved in the evaluation of the ranking of methods and instruments, which does not allow the results to be interpreted for global supply chains. An important direction for future research is to evaluate and rank methods and instruments, considering the constraints on available resources for effective implementation of GLM and GLI in supply chains.

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