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Article

Implementation of Sustainable Motorways of the Sea Services Multi-Criteria Analysis of a Croatian Port System

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Abstract: Motorways of the Sea present a practical example of combined and sustainable transport. With respect to the present model of functionality of the transport system in the Republic of Croatia, where the development of the port and of the gravitational transport system is left to each individual port (six independent ports), and where there is no systematic approach to specialization of each port or route, the results of the analysis are not promising. The goal of this research is to explain why the current Motorways of the Sea implementation model is inefficient and unsustainable. The analysis shows that a scientific approach to multicriteria analysis, which includes the identification of all relevant factors, the analysis of the transport infrastructure, as well as the identification of criteria which could potentially affect the Motorways of the Sea system, can correctly define the optimal model for the implementation of a sustainable Motorways of the Sea system.

Keywords: Motorways of the Sea; port system; multi-criteria analysis; Republic of Croatia; scenarios; sustainability

1. Introduction

The subject of this article is to research, elaborate on, and consistently define all of the relevant factors necessary for the successful implementation of a sustainable Motorways of the Sea system in Croatia. Moreover, in accordance with this, the goal is to suggest an optimal model aimed to create a sustainable Motorways of the Sea system, which would then enable further growth and development of intermodal transport, as well as the economic system.

Transportation is a multimodal, multi-problem, and multispectral system, as it involves different categories and activities, such as policy-making, planning, designing, infrastructure construction, and development [1]. On one hand, transportation is one of the main factors of economic growth and quality of life; on the other hand, it is one of the main causes of environmental pollution [2]. From the worldwide perspective, the energy consumption related to transportation amounts to one-third of total energy consumption globally, making transportation sector the second largest energy consumer (after industry) [3].

Road transport causes a negative impact both on the environment and society [4]. This negative impact is especially noticeable through frequent traffic congestion and a higher risk of traffic accidents, a higher level of noise, and exhaust gases, directly emitted by transport vehicles [5–8]. Additionally, there are also secondary negative impacts, such as the quantity of gases emitted in the production process of motor fuels, and an increased level of stress to all types of motorists and pedestrians [9,10]

Within the framework of the European transport policy and as a cornerstone of the EU supporting the efficient integration and cohesion of its internal market, the Motorways of the Sea concept was

introduced as an effective means to alleviate congestion from road transport infrastructure [11]. The Motorways of the Sea concept aims to introduce new intermodal maritime-based logistics chains in Europe, which should improve European transport organization [12]. All this clearly illustrates that road transport has certain limitations, with an expressed, negative influence on the environment and society. Therefore, it is more than necessary to find and develop alternative traffic solutions, such as Short Sea Shipping and Motorways of the Sea that include two or more transport modes. In this sense, a port represents the hub where all transport technologies (road, railroad, ship, and barge) merge and interact with one another. To ensure the competitiveness of the intermodal system, with respect to conventional road transport, a port has to be very fluid. The major threats here are capacity, the efficiency of transshipment and the interactions with other modes of transport [13,14]. In the process of transport planning, the choice of a port significantly impacts the route for further transport to the final destination. A route that is more competitive and attracts a larger quantity of freight, will also achieve a greater social and economic effect in that area. For this reason, this research is focused on the port system and related traffic infrastructure.

We use a multi-criteria analysis method to make a clear differentiation when comparing various scenarios of implementation of sustainable Motorways of the Sea services regionally and nationally. Only a systematic approach to the development of a traffic route can achieve an effective and sustainable result. To develop efficient and sustainable Motorways of the Sea services, the port system needs to be divided into elements, and bottlenecks must be identified. This will be researched on the example of the Croatian seaport system.

The first part of the paper (Sections 2 and 3) sets the theoretical framework of multimodal transport, sustainability, and Motorways of the Sea system and presents an overview of previous research. Section 4 identifies the relevant criteria, criteria weights, and criteria groups for the successful analysis of the Motorways of the Sea system. Section 5 elaborates research scenarios for the multi-criteria analysis, based on five selected port models. Section 6 is devoted to the definition of criteria weights, the multi-criteria analysis, and strategic guidelines and suggestions for a possible Motorways of the Sea model implementation in the Republic of Croatia.

2. Theoretical Framework

Multimodal logistics (including maritime transport and port handling) presents a continuous challenge for freight owners, because it affects both the costs and delivery time, therefore affecting transport sustainability. Multimodal maritime cargo transport encompasses cargo loading at the port of origin, transportation to its destination, including a sequence of at least two transportation modes (transfer from one mode to the next being performed at an intermodal terminal) [15]. Several initiatives aimed at achieving the sustainability in transport in the EU exist, such as Trans-European network (TEN-T), a project of Motorways of the Sea (MoS) under the Short Sea Shipping Platform [16]. Bamwesigye and Hlavackova [17] identified the three core values of sustainable transport: First, it should provide safe and consistent access to the basic needs of both the individuals and the society, while also securing both human and ecosystem health to ensure stability for the future generations. Second, it should present “value for money” by efficient operations and affordability while offering alternative means of transport. Third, the core goals of sustainable transport must be the global waste management and emissions control. The overall goal of sustainable transport should be providing mobility that ensures regional economic development and long-lasting future for natural resources [17]. Sustainable transport and sustainable logistics are declared as key areas in which sustainable interventions could have the largest impact in terms of enabling more sustainable trajectories [18]. In the context of transport, a focus has often been put only on economic outcomes, with less consideration being given to the social and environmental aspects [19].

Transport is regarded as one of the most important sectors of the European economy [20]. The creation of an effective multimodal transport network, which integrates sea and inland waterways, land transport, and air transport, has been recognized as a very important aspect of sustainable development

of the EU transport sector [21,22]. This should embody smartness, sustainability and inclusiveness, the key drivers of a Blue Economy [21]. Blue Economy refers to the use of seas and coasts for economic activities [23]. According to Tonković [24], the blue economy focuses on sustainability but is not limited to mere conservation. This form of economy encourages renewal. Based on these principles, the EU has created the Trans-European Transport Networks (TEN-T) [21], consisting of two layers of planning: the Comprehensive Network (covering all European regions) and the Core Network (most important connections within the Comprehensive Network linking the most important nodes) [25].

The Motorways of the Sea concept was first mentioned in the 2001 Transport White Paper. The concept aims at introducing new intermodal maritime based logistics chains to bring about a structural change to the organization of transport: door-to-door integrated transport chains [26]. The White Paper defined that the MoS should be part of the trans-European network (TEN-T) and funds should be made available for MoS development [12]. Motorways of the Sea is the maritime pillar of the TEN-T. It consists of short sea routes, seaports, associated maritime infrastructure, equipment, facilities, and relevant administrative formalities [27]. During the last 20 years, the EU has encouraged the promotion of Short Sea Shipping corridors (short sea routes) as a more sustainable alternative to road transport. The need to establish an even environment between different transport modes, as well as the need for reducing congestion and other environmental harmful impacts from road transport, have been the main motivations [28].

All transport modes require energy and pollute the environment including greenhouse gases (GHGs), directly or indirectly. However, according to Ehlers, [29], maritime transport is an environmentally friendly way of transportation. Maritime transport is the main mode of global transport and is one of the globalization cornerstones [30]. Almost 80 percent of global trade in goods is transported by sea [31].

Seaports, as a part of MoS, are the main nodes of maritime transport as well as basic links in the sea to land transport chains [32], and are essential for supporting the economic activities in the surrounding areas [33]. In the Delloite's "Study on Global trends to 2030: Impact on Ports Industry", sustainability was identified as one of the key issues for the seaport future [34]. Slinger et al. consider the sustainability to be a basic requirement in port business [35]. Seaports are located in a unique embedded position in the transport chain, enabling them to provide incentives to industry stakeholders in their effort to improve the sustainability of the industry. Furthermore, sustainable business is inevitable for seaports due to the customers which require green supply chains initiatives that strengthen the sustainability of the ports [36]. The sustainable seaport business can be achieved by appropriate planning and management of seaports and balancing economic, environmental, and social interests through mediation and open dialogue [37]. Managing different stakeholders and stakeholder interactions is of crucial importance in improving sustainable seaport business [38].

3. Previous Research

By analyzing relevant scientific and professional literature sources from the subject field, we highlighted the following studies and authors. Baird (EU Motorways of the Sea Policy 2005) [39] presents measures taken by the European Commission in the attempt to develop Motorways of the Sea systems, as well as the activities that are being undertaken. In the study "The Economics of Motorways of the Sea" (2007) [40], the same author presents the system's relevant elements and the economic aspect and advantages in comparison with land transport.

López-Navarro, in the paper "Environmental Factors and Intermodal Freight Transportation: Analysis of the Decision Bases in the Case of Spanish MoS" [41], evaluates the role that different agents may play in decision-making about the modal choice, considering environmental aspects. Furthermore, the author uses the values the European Commission provides in calculating external costs for the Marco Polo freight transport project proposals (call 2013) to estimate the environmental costs for several routes (a total of 72), comparing the use of road transport with the intermodal option that incorporates the Spanish MoS.

Kegalj and Traven, in the paper “Influence of Cargo flows on Sustainable Development of East Mediterranean Motorways of the Sea” [42], study the influence of cargo flows on the sustainable development of the Motorways of the Sea in the east Mediterranean and the applicability of the general framework of Motorways of the Sea policy. The paper emphasizes the advantages and significance of coastal traffic connections and the Motorways of the Sea and identifies the limitations. It analyses the corridors in the Mediterranean countries relevant for the traffic development of the region.

Bešković, in the paper “Possibilities for Motorways of the Sea development in the eastern part of the Adriatic Sea” [43], analyzes wider perspective on Motorways of the Sea development possibilities in the Adriatic Sea, especially on the eastern coast of the Adriatic Sea. A complete overview of Motorways of the Sea development is presented, and key elements that influence the development of Motorways of the Sea are analyzed. The author concludes that a lot of bottlenecks exist regarding the transport infrastructure in Southeast Europe. In another paper, “Importance of Short Sea Shipping and Sea Motorways in The European and Slovenian Transport Policy”, Bošković [44] provides a sound description of Short Sea Shipping and Motorways of the Sea as an innovative method which is aimed at shifting the increased road traffic to the alternative method of transport—sea transport.

Tsamboulas, Moraiti, and Vlahogianni, in the study “Assessing the Effect of Infrastructure and Service Attributes on the MoS Realization” [45], present Bayesian networks as a relevant model to evaluate different scenarios in function of transport development. Jugović, Žgaljić, and Poletan Jugović, in the paper “Model of encouragement for the development of intermodal transport in the Adriatic region” [46], present the necessary steps in the development of intermodal transport at the regional level while Dundović, Jugović, and Žgaljić, in the paper “Analysis of Croatian ports in respect to MoS implementation” [47], elaborate the Croatian port system on elements that support the potential success of introducing Motorways of the Sea services.

Jugović, Žanić Mikuličić, and Maglić, in the paper “Impact of external costs on the implementation of MoS system” [48], analyze external costs and their potential impact on maritime highway project implementation. Jugović, Cukrov, and Poletan Jugović, in the paper “Multi-Criteria Optimization of MoS in the Function of the Environment Protection: Case Study of Croatia” [49], set out the ecological and socio-economic criteria to directly relate to preserving the environment and protecting society.

Kavran, Jugović, and Kavran, in the paper “Adriatic Motorways of the Sea Analysis” [50], present results of research on Adriatic Motorways of the Sea project, IPA Adriatic Cross-border Cooperation Programme, during 2014.

Based on the analysis of the relevant literature, the conclusion is that the authors have focused on environmental factors, economic aspects, intermodal freight transportation, comparison with land transport, the roles that stakeholders may play in decision-making, the influence of freight flows on sustainable development, etc. in terms of MoS. In this paper, the focus will be on the analysis of the traffic route potential within the included Croatian (and regional) ports, with the aim to initiate sustainable Motorways of the Sea services.

4. Relevant Criteria for a Successful Implementation of the Motorways of the Sea System

The direction in which ports in a certain area develop, specialize, and interact is difficult to determine without a systematic analysis of the criteria set to achieve a successful MoS system. First, the criteria according to which it is possible to evaluate the suggested port models for the implementation of a MoS system need to be determined.

The determined criteria are the result of authors’ conclusions based on previously stated desk research, previous traffic system analysis and of the MoS system, direct interviews with 12 leading European experts, and a pre-survey conducted through online and live questionnaires aimed at defining models, measures, and activities for the implementation of a sustainable MoS system. Note that the criteria determined in this research are general criteria for the successful implementation of the Motorways of the Sea system, and could be used not only in Croatia, but universally.

Twelve leading European experts in the seaport management field, short sea shipping, and Motorways of the Seas were interviewed, which helped determine the criteria offered to respondents in the survey. When asked about each criterion, the respondents were expected to supply two answers: the current status of the selected criteria in their port (or country), and the relevance/importance and impact of selected criteria on the implementation of MoS service. The research idea was to isolate the most important and relevant criteria that are pertinent to the port business. Subsequently, the isolated criteria were then grouped into criteria groups, according to expert opinions.

Apart from interviewing the above-mentioned 12 experts, the authors have prepared a questionnaire (see Supplementary), consisting of 86 questions (out of which, 82 were criteria questions). These questionnaires were sent to 169 experts (36 questionnaires were received fully completed and were processed). The experts included top managers from all major ports in the Adriatic and the European Union, and experts in the maritime transport field and transport in general. The questionnaires were also distributed to European Commission staff responsible for the development of maritime transport; Short Sea Shipping and TEN-T corridors; all Short Sea Shipping Promotion Centers in Europe; and, through them, all European ports. The main goal of the questionnaire was to determine the relevance of each of the individual criteria. Based on the collected data on the current status and conditions of the ports' infrastructure and administrative processes, ports can be compared individually, but also according to the models (scenarios) for the implementation of a sustainable Motorway of the Sea system.

Resulting from the interviews and survey responses, 31 criteria were isolated, which were grouped into three main criteria groups, according to which it was possible to evaluate the suggested models for the implementation of a Motorways of the Sea system. The three criteria groups are listed below.

- Infrastructural criteria group.
- Interaction with different transport modes criteria group.
- Administrative-political criteria group.

4.1. *Infrastructural Criteria Group*

The analysis of infrastructural criteria clearly indicates that infrastructure is essential in ensuring the reliability of the Motorways of the Sea system and that only an infrastructure with sufficient capacities can provide for a large freight flow through the traffic route. Infrastructural criteria group consists of the following criteria.

1. Direct connection to railroad infrastructure
2. Direct connection to highway network
3. Safety of railroad infrastructure
4. Safety of road infrastructure
5. Maintenance of railroad infrastructure
6. Maintenance of road infrastructure
7. Capacity of railroad infrastructure
8. Capacity of road infrastructure
9. The condition and capacity of terminal infrastructure for trucks
10. The condition and capacity of terminal infrastructure for terminal vehicles and mobile equipment
11. Parking space capacity (in and around the port)
12. The existence of a Terminal Operating System
13. Appropriate port equipment for the manipulation of containers and trailers
14. Appropriate sea depth
15. Prioritization for regular service vessels
16. Pilotage exemption
17. Tug service exemption

From the available data, note that the major difference among ports within the Republic of Croatia is in port accessibility and land-based terminal infrastructure.

The development of the appropriate infrastructure (that will encourage sustainable business), whether it is regarding road or railroad connections, or a terminal, requires significant funds and it usually does not depend on the terminal itself, but on a national political decision.

4.2. Criteria Group “Interaction with Different Transport Modes”

Criteria group “Interaction with different transport modes” consists of the following criteria.

1. Number of Short Sea Shipping services
2. Number of permanent representatives of shipping companies
3. Number of block-trains
4. Number of railway operators in the country
5. Attractiveness of port services for trucks
6. Existence of a Port Community System
7. Prioritization of the Motorways of the Sea services

As interactions between different transport modes take place in a seaport, the single port becomes an important link in the creation of competitiveness for the Motorways of the Sea system as well as a base of sustainable maritime transport and seaport business. Equally important are the communication and flow-through of that interaction with ships, railroad, or road systems, as if only one of those connections is not reliable, it will impact the entire Motorways of the Sea system and service. In this respect, it is more difficult to improve all three aspects of sustainability (economic, environmental and social). This is a criteria group where external factors, such as railroad and maritime operators, play an important role. However, the function and responsibility of a port is to find a common way and a common solution to conform completely to regulations, raise the level of quality, and achieve sustainable business. Interaction does not only regard the execution of services and connections, but also regards the communication. The organization of road transport is very simple. There is no interaction with other transport modes or exchange of documents among a large number of participants. In the case of MoS systems that is precisely the problem, and a major threat is insufficient communication, decreasing sustainability. Information technology can rectify this problem, and its implementation in the Motorways of the Sea system would be beneficial to all users, therefore increasing all three aspects of sustainability (reducing costs, reduction, or even elimination of paper-based documents improved communication and the exchange of information between stakeholders, etc.).

4.3. Administrative-Political Criteria Group

The administrative-political criteria group comprises of the following criteria.

1. Motorways of the Sea service marketing
2. MoS service ICT support
3. Systematic bottleneck identification
4. Systematic quality management of Motorways of the Sea service
5. The complexity of organization and operations
6. The advantage of increased capacity as a result of port clustering
7. Political decision-making

All criteria are very important for the analysis of the possible port models (models of introduction of Motorways of the Sea systems). The first four criteria (related to the service management system) aim to raise the level of competitiveness of the system towards road transport modes and competitive routes, in a sustainable manner. These criteria are not currently implemented in the Republic of Croatia, but their development and introduction must definitely be encouraged.

The criteria related to the port system quality management and port clustering regard the possibility of associating with more ports (nationally or regionally) in a port cluster, which would increase the capacity of the ports. However, it complicates the management of a larger and more complex port system. Furthermore, management of port systems needs to be environmentally friendly, have low carbon footprinting, and be affordable and socially inclusive, both in the segment of administrative formalities and cargo management [37]. The proper quality management is an important factor in achieving the goals of sustainability.

The analysis of port models, carried out based on the above criteria, will allow Croatian national authorities to decide on whether to encourage the sustainable development of all ports equally, or to concentrate the investments in only one or two ports.

5. Scenarios for the Multi-Criteria Analysis

The Republic of Croatia, its seaports, and traffic system, including regional ports, have been chosen to test the suggested port models by applying multi-criteria analysis to different scenarios (the aim was to research one scenario per each seaport model). Port models are based on the expert knowledge (obtained through the aforementioned interviews and questionnaires), and through desk research from scientific and professional papers. The identified models and multi-criteria scenarios have been modified according to the present condition of the transport system in the Republic of Croatia. In this way the scenarios, which were analyzed using the previously defined criteria groups, were developed.

Following are some of the characteristics of Croatian seaports and traffic system.

- The port system is comprised of six ports, without any preference to any particular port in the current functioning and development.
- All ports are relatively weak from an infrastructural and organizational point of view, leaving significant room for improvement and sustainable development.
- Port systems in the surrounding area have many well-developed ports in various countries (Italy, Slovenia, Montenegro, Albania, and Greece).
- Successful Motorways of the Sea services pass through some of these ports in the surrounding areas and they are a prime example of success in the EU.
- Most of the traffic which passes through Croatian ports is destined to other countries in the European Union.
- Part of the traffic through Croatian ports is destined outside of the countries of the European Union

The multi-criteria decision-making process has been conducted for the following scenarios, based on the five port models.

1. Scenario based on the model of independent ports (IP model): Rijeka, Zadar, Split, Šibenik, Dubrovnik, and Ploče.
2. Scenario based on the model of nationally grouped ports (NGP model):
 - The port of Rijeka, which represents a unit per se.
 - Ports of the Central Dalmatian area: Zadar, Šibenik, and Split.
 - Ports of the Southern Dalmatian area: Ploče and Dubrovnik.
3. Scenario based on the model of regionally grouped ports (RGP model):
 - North Adriatic ports: Venice, Trieste, Koper, and Rijeka.
 - Ports of the Central Dalmatian area: Zadar, Šibenik and Split.
 - Ports of the Southern Dalmatian area: Ploče and Dubrovnik.

4. Scenario based on the model of a single port—Rijeka (SP model): Rijeka as port of national priority for Motorways of the Sea services. Only the data for the Port of Rijeka was inserted, because in that scenario only the Port of Rijeka would be developed as a port of national priority for MoS services, due to the fact that it is the largest and most developed port in Croatia, Other ports could not be considered as the ports of choice for MoS services in the “single port” model, due to their underdevelopment and size.
5. Scenario based on the model of two ports—Rijeka and Ploče (TP model): two of Croatia’s largest ports (Rijeka and Ploče) would be equally developed and would hold the same status for MoS services with regard to the container and RO–RO traffic. Therefore, only the data related to those two ports was used in the multi-criteria analysis.

The grouping of ports is possible only if port operators, as private (commercial) entities, recognize the economic (financial) benefits of grouping. The grouping of ports can be conducted as follows,

- (a) taking ownership or control of one company over the other and thus ensuring that one operator manages multiple terminals in multiple ports;
- (b) business association according to a joint venture model (well known in shipping industry), where different operators pool their capacities, but each offers its share separately to the market in a “pooled capacity”; and
- (c) association for the purpose of promotion (without pooled capacities). For example, NAPA (North Adriatic Port Association) represents an association with the purpose of promotion. In this respect, four ports (Venice, Trieste, Koper, and Rijeka) combine their strengths to promote the Northern Adriatic route and present themselves as an alternative to the European ports [51].

To obtain input data for the scenario analysis, further desk research and analysis of available data was conducted. The current status and conditions of 31 criteria in nine ports (Rijeka, Zadar, Šibenik, Split, Ploče, Dubrovnik, Venice, Trieste, and Koper) were mapped and inserted in the software.

6. Multi-Criteria Analysis as a Tool for Successful Development and Implementation of Motorways of the Sea Services

The use of a multi-criteria analysis process is common when trying to elaborate and analyze different traffic issues and strategies. According to Borza et al. [52], “multi-criteria analysis (MCA) is used to highlight the rationale and subjective views of stakeholders in relation to each problem”. It is usually used to synthesize opinions expressed, prioritize structures, analyze conflict situations, make recommendations, and/or provide operational advice.” MCA has been widely used to deal with decision problems including multiple criteria [53].

MCA possesses the ability to deal with ranking of many alternatives based on conflicting criteria, and it has been one of the fast-growing areas of Operational Research in the past 20 years, with various applications [54]. According to Karleuša [55], “MCA provides a systematic methodology to integrate heterogeneous and uncertain information with cost–benefit information and stakeholders views in an understandable framework to rank project alternatives. Multi-criteria analysis is a highly useful tool for project evaluation during the developing phases when decision makers do not possess sufficient knowledge regarding the details, but the importance of making the right decision is considerable.”

To carry out the multi-criteria analysis process, the PROMETHEE (Preference Ranking Organization METHod for the Enrichment of Evaluations) software (version 1.3.1.0.—Academic Edition, developed by professor Bertrand Mareschal and Jean-Pierre Brans from Université Libre de Bruxelles, Belgium) has been used during the research. Visual PROMETHEE software uses the average weights and the performance/effectiveness assessment according to experts for each alternative (scenario) per criterion (in this case, criteria group). The application can assess which alternatives can be considered best with respect to the criteria per scenario [56]. The Visual PROMETHEE can handle differences among evaluations of variants, made for all criteria [57]. Successful application of the PROMETHEE methods

to various fields is evident (investments, banking, chemistry, medicine, tourism, etc. [58]. According to Yu et al. [59], PROMETHEE is one of the most popular MCA methods: “It takes advantage of the outranking principle to rank alternatives. As the procedure of PROMETHEE is very easy and transparent, it can be easily understood by decision-makers and can offer a reasonable ranking of all alternatives.” According to Aljohani et al. [60], PROMETHEE method is considered a relatively simpler ranking approach compared with other MCA methods. It has been successfully utilized in numerous decision-making problems in various fields which include transport and logistics over the last years. The reason for this is its user-friendly application and mathematical properties.

6.1. Definition of Criteria Weights

When analyzing and searching for an optimal solution for the implementation of a sustainable MoS system, it was not possible to use only the previous research and previously defined criteria (as stated above) and criteria weights, as this type of research has never been published. Therefore, it was necessary to define the criteria weights.

The criteria weights were assigned by the survey respondents, who assigned values from 1 (least relevant or important) to 10 (most relevant or important) to each criterion. To insert the criteria weights in the software, the authors decided to use the scale from 1 to 3. Criteria that received the average relevance/importance ranking of less than 5 (by the survey respondents) were not considered and were dismissed. Criteria that received the average relevance/importance ranking from 5 to 6 were assigned a numerical value of 1 (Minor criteria weight). Criteria that received the average relevance/importance ranking from 7 to 8 were assigned a numerical value of 2 (Medium criteria weight). Criteria that received the average relevance/importance ranking from 9 to 10 were assigned a numerical value of 3 (Major criteria weight).

The experts provided the following comments when assessing the criteria within the infrastructural criteria group.

- Considering that large financial investments are a common characteristic to numerous criteria in this criteria group, the criteria that require new and significant infrastructural investment have been evaluated with a major criteria weight. These are the requirements (usually construction) for direct connection to the railroad infrastructure and highway network: a sufficient railroad and road infrastructure capacity, a sufficient parking space capacity, the existence of a Terminal Operating System, appropriate port equipment for the manipulation of containers and trailers, as well as appropriate sea depth. All of these are criteria should be fulfilled because they represent basic preconditions for reliable, successful, and sustainable Motorways of the Sea systems. Otherwise, it would be difficult to expect a long-term success of the Motorways of the Sea system through that specific route.
- The criteria such as safety of railroad or road infrastructure, the maintenance of railroad and road infrastructure and the condition and capacity of terminal infrastructure for trucks, terminal vehicles and mobile equipment have been evaluated with a medium weight. This is because these are the criteria that can be compensated for, as their negative impact can be reduced if terminal operators invest additional effort. With the railroad or road infrastructure process optimization, as well as the operator’s experience, these criteria can be brought to a level where they are not creating a bottleneck effect, and where a major infrastructural investment is not needed.
- The criteria of prioritization for regular service vessels and exception from the obligatory use of tugboats or pilots are unfortunately not in force or do not exist in the Adriatic port systems which are being used in the model scenarios, therefore they cannot be evaluated with major or medium weights. These are organizational criteria, for which it is assumed that their value will be recognized only in the future, therefore they have been evaluated with a minor weight.

The experts provided the following comments when assessing the criteria within the criteria group “Interaction with different transport modes”.

- Experience is an extremely important issue when introducing new transport services, or ensuring the perfect functioning of the existing ones, and therefore the current number of Short Sea Shipping services and block-trains is important and has been evaluated with a major weight. The same applies to the number of permanent representatives of shipping companies and the number of railway operators. Port terminals with no experience or limited experience in serving regular maritime and railroad services need some time to optimize the processes, that is, to increase the fluidity of transportation through ports, which represents the precondition for sustainable Motorways of the Sea services. This applies to all participants in the transport process, not only to terminal operators.
- The existence of a Port Community System and the attractiveness of port services for trucks are essential in case of a major terminal workload, when terminals function close to the upper limit of their capacities. Considering that this is not the case with the observed ports, these criteria have been evaluated with a medium weight.
- Prioritization of the Motorways of the Sea services is of major importance when ensuring an optimal freight flow-through; however, none of the analyzed ports implement this option. Therefore, for an objective comparison, this criterion has been evaluated with a minor weight. In case any of the ports should introduce the prioritization of Motorways of the Sea services, this criterion should be evaluated with a major weight.

The experts provided the following comments when assessing the criteria within the administrative-political criteria group.

- The system of promoting (marketing) Motorways of the Sea service, the ICT support for the service, the systematic identification of bottlenecks, and the systematic quality management are all criteria that directly impact the Motorways of the Sea service. They do not require major financial investments, but mostly require the initiative and efforts by those responsible for the functioning of the port and for the traffic system (both policy makers and administrative bodies). In the observed examples, these are the governments and the port authorities, whose main interest should be the development of transport system their area. These criteria have been evaluated with the major weight, the same as the political decision-making criterion, which carries the strategic orientation of a government, in planning the transport system. The consequence of this is the development of one or more routes, and capital investments in infrastructure.
- As the experience in the functioning of port systems can account only for minor deviations from the ideal management of the port (or the group of ports), and all ports in this research are located in the European Union Member States, the “Complexity of organization and operations” criterion has been evaluated with a medium weight.
- An increased port capacity is truly an advantage. However, from the aspect of service organization and as Motorways of the Sea systems have precisely defined ports of origin and destination, the fact that available capacity in a port within the same group still exists, but in a different location, does not represent a special advantage. Therefore, the “Advantage of increased capacity as a result of port clustering” criterion has been evaluated with a minor weight. The exception would be in cases where ports are very close and well connected (both in the traffic sense and information-wise), which would allow the increased collaboration between the ports (for example the use of the free capacity of one port as a storage space for the other port).

6.2. Application and Results of the Multi-Criteria Analysis

Taking into consideration the research conclusions reached so far, the identified scenarios will be analyzed through several different criteria group combinations. The scenario ranking was performed including

- only the influence of infrastructural criteria group,

- only the influence of criteria group of interaction with different transport modes,
- only the influence of administrative-political criteria group,
- simultaneous influence of infrastructural criteria group and the criteria group of interaction with different transport modes,
- simultaneous influence of infrastructural criteria group and administrative-political criteria group,
- simultaneous influence of administrative-political criteria group and the criteria group of interaction with different transport modes, and
- simultaneous influence of all three criteria groups (infrastructural criteria group, criteria group of interaction with different transport modes and administrative-political criteria group).

After the insertion of data, the PROMETHEE software (version 1.3.1.0.—Academic Edition) has calculated a scenario ranking (in other words, a preference order of alternatives), which is based on the given influences of the criteria groups (three scenario rankings) or combinations of criteria groups (four scenario rankings).

According to Antunes et al., PROMETHEE is a pairwise comparison-based outranking methodology used to compare and evaluate a finite set of alternatives in terms of multiple criteria [61]. PROMETHEE software allows for a comparison between scenarios (the preference order), given the influence of each criteria group or criteria groups combination. According to Nikolava et al. [62], PROMETHEE offers the calculation of preference degree of one alternative over another alternative, which is used for the ranking of the alternatives based on the so-called positive and negative flows, respectively, $\phi+$ and $\phi-$. There are two main approaches for ranking of the alternatives: PROMETHEE I and PROMETHEE 2 methods. The PROMETHEE Flow tables contain the results of both methods: PROMETHEE I method and PROMETHEE II method. Working with those tables, the analysts can make conclusions about the relationships established between any two alternatives.

PROMETHEE I method establishes one of the 4 types of relations between alternatives: the indifference, incomparability, strict preference, and strict antipreference. The positive and negative flows are used to gain a partial pre-order. The larger $\phi+$, the more the alternative dominates the other alternatives. The smaller $\phi-$, the less the alternative is dominated [62].

PROMETHEE II method establishes one of the three types of relationships: indifference, strict preference and strict antipreference [63]. The PROMETHEE II method has been selected for conducting the presented study. Compared to the other versions, which can be viewed as extensions of the original methodology, PROMETHEE II offers complete ranking of the alternatives (pre-order). An in-depth explanation of PROMETHEE procedures can be found in the PROMETHEE 1.4 Manual [64].

Due to time and space constraints, the authors decided to focus only on the scenario ranking, based on the influence of determined criteria group or a combination of criteria group. The alternatives were evaluated and compared according to the minimum or maximum values of the criteria. As stated above, the criteria weighting and the criteria preference function are two important segments of PROMETHEE II [56]. The preference functions of PROMETHEE for each criterion reflect the intensity of preference of one alternative over another. According to Brinkhoff, values of the preference function can be between 0 and 1 [61].

The multi-criteria analysis usually starts by identifying the alternatives and defining the criteria, as stated above. The deviations of the criteria of alternatives are determined based on pairwise comparisons. Next, a relevant preference function for each criterion was determined. Then, the global preference index was calculated. The positive and negative outranking flows were calculated for each alternative. Next, the net outranking flow for each alternative and complete scenario ranking was calculated. Finally, the software performed the sensitivity analysis of the weighting and the calculation of the complete final scenario ranking.

The scenario ranking for the implementation of a sustainable MoS services, on the example of the Republic of Croatia (and several regional ports), is shown in Table 1, where 1 represents the highest

ranked model according to these criteria groups (or combinations of criteria groups) and 5 represents the lowest ranked model.

Table 1. Scenario ranking according to the influence of determined criteria group or a combination of criteria groups.

Criteria Group Combination	Model of Independent Ports (IP Model)	Model of Nationally Grouped Ports (NGP Model)	Model of Regionally Grouped Ports (RGP Model)	Model of a Single Port (SP Model)	Model of Two Ports (TP Model)
Based on the infrastructural criteria group	5	4	3	1	2
Based on the criteria group of interaction with different transport modes	4	2	1	5	3
Based on the administrative-political criteria group	5	4	3	2	1
Based on the simultaneous influence of infrastructural criteria group and criteria group of interaction with different transport modes	5	4	3	2	1
Based on the simultaneous influence of infrastructural and administrative-political criteria groups	5	4	3	1	2
Based on the simultaneous influence of administrative-political criteria group and criteria group of interaction with different transport modes	5	3	1	4	2
Based on the simultaneous influence of all three criteria groups	5	4	3	2	1

When implementing a sustainable Motorways of the Sea service, based only on the infrastructural criteria group, the lowest ranked model is the model of independent ports. This is understandable, as most infrastructural criteria imply significant infrastructural investments in ports and accesses to ports; therefore, investing in numerous ports presents a significant financial burden for the investors. In the same way, the model of nationally grouped ports holds an unfavorable 4th position, whereas the model of regionally grouped ports is somewhat more advantageous and is placed in the 3rd position. The model of a single port is ranked first, and the model of two ports is ranked second.

When ranking the scenario of implementation of a sustainable MoS, based only on the influence of the criteria group of interaction with different transport modes, the software presents interesting results. In comparison to the previous scenario, in this specific ranking the results are almost opposite. The model of regionally grouped ports is the best choice, whereas the model of nationally grouped ports is positioned second, followed by the model of two ports and the model of independent ports. The single port model received the lowest ranking.

A scenario ranking under the influence of an administrative-political criteria group only shows that the two ports model is the optimal solution, while the single port model is the next most favorable. The software shows the model of regionally grouped ports as the third option and the model of nationally grouped ports as the fourth option. In the last position, we can see the model of independent ports.

What follows are four scenario rankings for the simultaneous influence of two or more criteria groups (simultaneous influence of the infrastructural criteria group and the criteria group of interaction with different transport modes, simultaneous influence of the infrastructural and administrative-political criteria groups, simultaneous influence of administrative-political criteria

group, and criteria group of interaction with different transport modes and the simultaneous influence of all three criteria groups).

In the scenario ranking for the implementation of a sustainable MoS system based on the simultaneous influence of the infrastructural criteria group and the criteria group of interaction with different transport modes, the Visual PROMETHEE software sets the model of two ports as the optimal solution, whereas the model of single ports can be found in the second position and the model of regionally grouped ports in the third position. Next is the model of nationally grouped ports, whereas the model of independent ports is ranked last.

When ranking a scenario of simultaneous influence of the infrastructural and administrative-political criteria groups, the model of a single port dominates and thus it represents the optimal solution, followed by the model of two ports, the model of regionally grouped ports and the model of nationally grouped ports. The least favorable solution is the model of independent ports.

In the following ranking, the simultaneous influence of administrative-political criteria group and criteria group of interaction with different transport modes, the best ranked scenario is the model of regionally grouped ports. This is understandable given the fact that different transport operators prefer the system where there is a multitude of ports, more combinations, and transport routes. In such a competitive environment, better commercial conditions can also be requested, affecting the economic aspects of sustainability. Following are the model of two ports and the model of nationally grouped ports. The least preferable solution is the model of independent ports, while the model of a single port is placed in the 4th position.

When ranking the scenario which includes the simultaneous influence of all three criteria groups, the model of two ports emerges as the optimal solution, whereas the models of a single port and the model of regionally grouped ports are ranked second and third. In the fourth place, we can find the model of nationally grouped ports, followed by the model of independent ports. Table 2 shows in detail a scenario ranking, for the implementation of a sustainable MoS system, which includes criteria groups or criteria group combinations.

6.3. Strategic Guidelines for Possible Implementation of the Motorways of the Sea Model in the Republic of Croatia

The analysis of the scenario ranking results demonstrates that the decision of implementation method for a sustainable Motorway of the Sea system of the Republic of Croatia is not simple and unidirectional, but is dependent upon a variety of elements. In the first place, these are the identified criteria, but also their weights, depending on the influence of the criteria. From the analysis of influence of each single criteria group as well as of all criteria group combinations, it may be concluded that, when implementing a sustainable MoS system in the example of the traffic system in the Republic of Croatia, three scenarios (models) stand out, which can be considered as possible choices. These are the model of two ports, the model of regionally grouped ports, and the model of a single port (see Table 1). The choice will depend on the type of initiative (capital intensive investments in infrastructure or easily achieved improvements in administration and organization of MoS services) and whether there is a synchronized development approach (which will be the subject of future research).

The model of two ports (Figure 1) is an optimal solution for the implementation of a sustainable MoS system in three cases: where the emphasis is placed on the administrative-political criteria group, as well as on the simultaneous influence of the infrastructural criteria group and the criteria group of interaction with different transport modes, and the simultaneous influence of all three criteria groups.

Table 2. Scenario ranking for the implementation of a sustainable MoS system (based on criteria groups or criteria group combinations). Source: Visual PROMETHEE software.

Criteria Group or Criteria Group Combination	Rank	Action	Phi	Phi+	Phi−
Based on the infrastructural criteria group	1	SP model	0.6000	0.7625	0.1625
	2	TP model	0.4375	0.6625	0.2250
	3	RGP model	0.0250	0.4313	0.4063
	4	NGP model	−0.2625	0.2687	0.5313
	5	IP model	−0.8000	0.0563	0.8562
Based on the criteria group of interaction with different transport modes	1	RGP model	0.7500	0.8472	0.0972
	2	NGP model	0.0417	0.2639	0.2222
	3	TP model	−0.1111	0.2083	0.3194
	4	IP model	−0.1806	0.1528	0.3333
	5	SP model	−0.5000	0.0556	0.5556
Based on the administrative-political criteria group	1	TP model	0.3333	0.5833	0.2500
	2	SP model	0.1806	0.5139	0.3333
	3	RGP model	0.0556	0.5278	0.4722
	4	NGP model	0.0417	0.4583	0.4167
	5	IP model	−0.6111	0.0972	0.7083
Based on the simultaneous influence of infrastructural criteria group and criteria group of interaction with different transport modes	1	TP model	0.2768	0.5223	0.2455
	2	SP model	0.2500	0.5357	0.2857
	3	RGP model	0.2321	0.5446	0.3125
	4	NGP model	−0.1652	0.2589	0.4241
	5	IP model	−0.5938	0.0893	0.6830
Based on the simultaneous influence of infrastructural and administrative-political criteria groups	1	SP model	0.4781	0.6886	0.2105
	2	TP model	0.4211	0.6447	0.2237
	3	RGP model	0.0000	0.4386	0.4386
	4	NGP model	−0.1623	0.3246	0.4868
	5	IP model	−0.7368	0.0702	0.8070
Based on the simultaneous influence of administrative-political criteria group and criteria group of interaction with different transport modes	1	RGP model	0.4286	0.7000	0.2714
	2	TP model	0.1000	0.3857	0.2857
	3	NGP model	0.0429	0.3571	0.3143
	4	SP model	−0.1929	0.2643	0.4571
	5	IP model	−0.3786	0.1286	0.5071
Based on the simultaneous influence of all three criteria groups	1	TP model	0.2905	0.5372	0.2466
	2	SP model	0.2331	0.5304	0.2973
	3	RGP model	0.1824	0.5338	0.3514
	4	NGP model	−0.1149	0.3074	0.4223
	5	IP model	−0.5912	0.0912	0.6824



Figure 1. Model of implementation of a sustainable Motorways of the Sea through two ports in the Republic of Croatia.

In the case of a simultaneous influence of the infrastructural and administrative-political criteria groups, or the influence of the infrastructural criteria group only, the model of a single port is greatly advantageous because the condition of the conjoined traffic infrastructure, as well as of the means of manipulation in the terminal of the port of Ploče, is at a very low level. When the road infrastructure, which is currently under construction, allows for an undisturbed connection to the highway network and the railroad infrastructure is brought to a level of regular functioning, the model of a single port will not be dominant anymore, leaving space to the model of two ports, which will be preferable.

In sum, the authors conclude that the model of two ports (Figure 1) is the ideal solution for the implementation of a sustainable MoS system in all cases, except two: the case where the influence of the criteria group of interaction with different transport modes is dominant, and the case where the simultaneous influence of the criteria group of interaction with different transport modes and administrative-political criteria group is dominant. In those two cases, the optimal choice is the model of regionally grouped ports (Figure 2).

Note that the infrastructural and political-administrative criteria groups require financial investments and therefore impose financial burdens on the government. In this sense, they are closely connected. The criteria group of interaction with different transport modes regards the activities and functionality of transport operators. In case the government should assess that its priorities and interest lie in the orientation towards Motorways of the Sea services and that the implementation will be initiated and conducted by the government itself, then these will be the criteria that will define the decision and the optimal and most sustainable model will be the model of two ports.

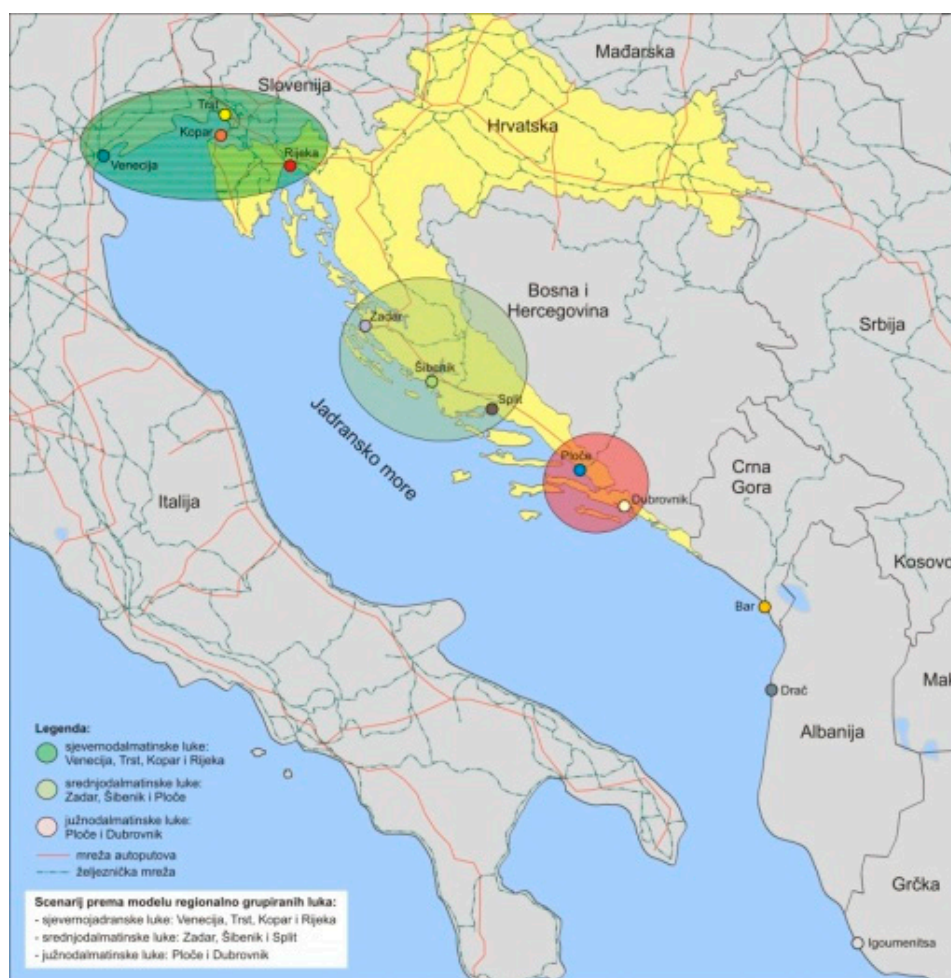


Figure 2. Model of implementation of a sustainable Motorways of the Sea system through regionally grouped ports.

Of equal value is the decision-making on whether the government will independently initiate the implementation and persevere on the independent development of the MoS system or, on the contrary, if it will share the efforts of introducing the system with private transport operators. In the case of a common, coordinated, and systematic introduction of a sustainable Motorways of the Sea system, the most suitable and sustainable solution would be to develop a model of regionally grouped ports.

With respect to the current traffic system model in the Republic of Croatia, where the development of a port and gravitational traffic system is left over to each port independently (six independent ports; scenario 1), and where there is no systematic specialization of each port, or route, the results of the analysis are not promising. The current model of implementation of the MoS system (considering also that the MoS systems are currently dominant in the entire European maritime exchange of goods), is completely wrong and there is not even one element that could justify its maintenance. Therefore, the analysis suggests the conclusion that through a scientific approach (which includes the identification of all relevant factors, the current analysis of the condition of the entire traffic infrastructure and the identification of criteria that affect the functioning of the MoS system) the existing model (six independent ports) can be evaluated, and the optimal model for the implementation of a sustainable MoS system can surely and precisely be defined.

Finally, the analysis of the research results brings out three key conclusions for the case of the Republic of Croatia:

- The current model (six independent ports) of the traffic and port system in the Republic of Croatia is completely inappropriate for the development and implementation of a sustainable MoS system, and it unfortunately represents the worst solution with respect to all of the identified models.
- In the case where the Republic of Croatia decides to neglect the development of MoS and this development is left (independently) to transport operators, the ideal model is the model of regionally grouped ports. Such a model implies the coordination and common efforts of the port systems in neighboring countries (Italy and Slovenia). Objectively, except in the case of the same owners, the efficient functioning of common port systems is quite difficult to achieve. Furthermore, the existence of multiple and uncoordinated heterogeneous ICT systems in different ports may contribute to the nonsustainable business due to increased waiting time, increased costs, increased processing time, etc.
- In the case where the Republic of Croatia decides to actively participate in the development of a sustainable MoS system, independently or in coordination with transport operators, the optimal model is the model of two ports. This model means specialization and government preference of two ports—Rijeka and Ploče (a focus on infrastructural investments in these ports)—while other ports will consciously be left to private investments and the development of other types of freight. This model represents the optimal solution for the implementation of a sustainable MoS system in the Republic of Croatia.

These conclusions were generated from the analysis of the current infrastructure conditions, the opinions of relevant experts and survey respondents, and from the multi-criteria analysis (based on the identified, weighted and grouped criteria). The results of the analysis will surely be different with the modification of any of these elements. In such a combination, models have been analyzed on the case of the Republic of Croatia, according to the current infrastructure conditions. The analysis is definitely applicable to traffic systems of other countries, whether it is a national system or a regional system. It may be expected that the same analysis, on the example of another port system, would result in different conclusions. Furthermore, the results of the analysis can be affected by modifying the criteria, criteria weights, or by changing the infrastructure conditions.

7. Conclusions

Intermodal transport implies a transport that includes two or more transport modes. In this sense, a port represents the hub where transport technologies (road, railroad, ship, and barge) conjoin. To ensure the competitiveness of the intermodal system (with respect to the conventional road transport) and to achieve sustainable business, a port has to ensure a sufficient cargo flow-through. The major threats can be found in the lack of capacity, the low efficiency of transshipment and poor interaction with other transport modes. In the process of transport planning, the choice of a port significantly affects the transport route. A route that is more competitive and that attracts a larger quantity of freight will also positively affect social and economic aspects of sustainability in that area. For this reason, this research focused on the port system and related traffic infrastructure.

Without a systematic analysis, based on the selected criteria used to implement a successful Motorways of the Sea system, it is difficult to define the direction in which ports of a certain area, will (or will not) develop, specialize, and cooperate. The Republic of Croatia, with its six major seaports and three ports in the neighboring region (Italy and Slovenia), has been chosen as a test field for the defined models and scenarios. The models have been defined according to the current status and conditions of the Croatian traffic and seaport system, and according to the literature review and expert knowledge (obtained through interviews and questionnaires) regarding the Motorways of the Sea services. Models and scenarios have been analyzed according to the defined criteria, which were weighted and grouped into three criteria groups. It was not possible to use the previous research to define the criteria and criteria weights, as they could not be found in the existing literature. It was therefore necessary to define the criteria and their weights, as well as the criteria groups.

The preliminary analysis of the scenario ranking results demonstrates that the selection of the implementation method for a sustainable MoS system in the Republic of Croatia is not a simple and unidirectional decision but depends on various elements. Primarily, these are the identified criteria, criteria weights, and criteria groups. From the analysis of the influence of each criteria group, as well as of all combinations of criteria groups, it may be concluded that, when implementing a sustainable MoS system in the Republic of Croatia, two scenarios (models) can be identified as possible choices. These are the model of two ports and the model of regionally grouped ports. The decision on which model to choose will depend on whose initiative we are dealing with (government initiative or private transport and logistics operators initiative) and whether there is a joint approach for development.

The model of two ports is an optimal solution for the implementation of a sustainable MoS system in three cases: where the emphasis is placed on the administrative-political criteria group, as well as on the simultaneous influence of the infrastructural criteria group and the criteria group of interaction with different transport modes, and the simultaneous influence of all three criteria groups. In the case where the influence of the criteria group of interaction with different transport modes is dominant, and in the case where the simultaneous influence of the criteria group of interaction with different transport modes and administrative-political criteria group is dominant, the optimal choice is the model of regionally grouped ports.

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