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An Approach to Optimize Container Locations in a Containership With Electre III

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ABSTRACT

A container ship is a vessel designed to carry containers and is now the main mode of sea freight in commercial ports. It is an integral part of world trade. Upon arrival at a seaport, the container ship stays inactive at the dock for the duration of loading and unloading operations. Handling operators at the port terminal are provided with a schedule showing the dates of loading and unloading of containers, as well as their locations in the container ship. An optimal location for a container in a container ship is very important for companies because this operation reduces transport costs. In this work, the authors propose an approach to solve the container placement problem through the description of a decision model that allows solving and optimizing the available storage space on a container ship. The objective of this work is to find the best location for all types of containers in the container ship based on the multi-criteria methods Electre III (elimination and choice expressing reality); in this contribution, four criteria are used: the container destination, the container weight, the departure date of a container, and the container type.

KEYWORDS

Container Departure Date, Container Destination, Container Type, Container Weight, Containership Loading, Decision Support System, Multicriteria Method

INTRODUCTION

Container ships are cargo ships that carry their entire load in truck-size intermodal containers. This is made possible by a technique called containerization. A container ship is constructed in such a way to easily stack standard intermodal containers near and on top of each other as well as on deck. Container ships move from one port to another by a route fixed to load and unload a large number of containers.

This article addresses the problem of container placement in a container ship to determine the optimal storage of containers to minimize unnecessary movements. The objective of the presented study is to manage the storage of different containers in a container ship by considering certain criteria for better storage based on a multi-criteria decision support method, which is the Electre III because of her strong potential for practical applications. The rest of the paper is structured as follows: section 2 presents the container ship loading problem. Section 3 presents a state of art for the various works that address the problem of container ship loading while positioning the contribution. In section 4, the

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authors introduce their model by demonstrating and explaining how it works. Section 5 contains the implementation part of the proposed approach. In section 6, they discuss the results produced by an application of their model. In section 7, they present the conclusion and the future research perspective.

THE CONTAINER SHIP LOADING PROBLEM

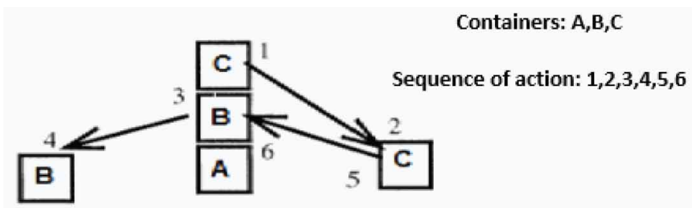
For many years, container loading has been a real problem in the maritime environment.

The handling of import or export containers leads to a lot of unnecessary movement or a reshuffling, consisting of unstacking several containers to reach a specific container placed under the bay.

Figure 1 shows the retrieval of a container from the middle of the bay, to retrieve container B, it is necessary to first remove container C, then retrieve container B and finally put container C back in the row. So, actions 1 2 and 5 6 are unnecessary displacements.

So, the problem that arises is how to determine the best storage of any containers to minimize unnecessary movements.

Figure 1. Retrieving a Container from the Middle of the Stack



RELATED WORKS AND CONTRIBUTION

Related Works

In this section, the authors review the different methods of container storage in a container ship, which have been considered in the past, to situate the present work.

In (Avriel & Penn, 1993; Avriel et al., 1998), a mathematical model for stowage planning for a container ship was presented without considering the stability of the ship. The goal was to minimize the number of displacements.

In the work of (Wilson & Roach, 2000), determining an optimal solution to the problem of loading and unloading containers seems difficult and even impracticable within a reasonable time. This is a complex problem, depending on the capacity of the ship and the number of containers unloaded and loaded at each port. Therefore, the authors of this paper proposed to break the process into two sub-processes, a strategic process, and a tactical planning process. In the first phase, a Branch and Bound algorithm was applied to assign each container to a block in the ship. The Taboo search is then used to assign containers to specific locations within the blocks determined in the first phase. Thus, acceptable but not always optimal solutions can be determined in real-time within a reasonable calculation time.

The work of (Imai et al., 2002) is one of the first models of stowage planning that considers the minimization of storage operations. The model formulated the stability of the boat only in terms of the distance between the center of gravity and the metacenter. No distinction was made between the different types of containers or between their destinations. An estimate of the number of maneuvers was calculated, which was also included in the objective function.

In (Imai et al., 2006), the authors included two new constraints for the calculation of stability (longitudinal and transverse stability of the ship) compared to their previous model. The problem was formulated as a multi-objective program in whole numbers. Because of the complexity of the model, the authors proposed a solution approach based on genetic algorithms.

The work presented in (Sciomachen & Tanfani, 2007) developed a heuristic algorithm to solve this same problem. The goal of the authors was to reduce the total loading time. A validation of the proposed approach with some test cases related to container ship docks at the port of Genoa (Italy) is given.

(Monaco et al., 2014) were involved in the problem of determining the optimal position of containers to be stored in a ship. They assumed that the ship's berthing along the quay is composed of several slots. They proposed a binary integer program and a two-step heuristic algorithm to obtain efficient solutions to the storage planning problem.

(Araújo et al., 2015) considered a three-dimensional container ship stowage planning problem. They developed a mathematical model to minimize the number of container movements and ship instability. A hybrid method was proposed to solve the model and obtain a good approximation of the Pareto front. Computational results reveal that the proposed method provides better solutions than the mono-objective simulated annealing algorithm.

(Ambrosino et al., 2015) extended the MBPP (Master Bay Plan Problem) to MP-MBPP (Multiport Master Bay Plan Problem) and proposed a heuristic algorithm based on an exact MIP (Mixed Integer Programming) model to minimize the ship's total berthing time. The proposed heuristic algorithm could find good solutions for all travel planning.

(Parreño et al., 2016) presented a new integer programming formulation and a greedy randomized adaptive research procedure (GRASP) to solve the problem of stowing containers in a container ship. The approach was able to provide a high-quality solution in one second.

In (Kroer et al., 2016), a general model of the container stowage problem was presented to reorganize containers in a single bay. The authors proposed two approaches, one based on binary decision diagrams and the other on DPLL (Davis–Putnam–Logemann–Loveland) solvers, to solve real-size and simplified instances.

(Li et al., 2017) studied the problem of container ship stowage along the entire Yangtze River route (China), which has its particularity. They addressed the problem of stowage planning through a two-phase approach including two-tier planning: MBPP on the complete route and Slot Plan Problem for each bay at each port on the route. The results of the first planning level are the entries of the second planning level at each port. They presented GRASP (Greedy Randomized Adaptive Search Procedure) and an evolutive heuristic algorithm to solve the stowage planning problem at each level respectively. The approaches were able to find high-quality solutions for both planning levels in two seconds.

(Zhang et al., 2018) treated the problem of planning stowage in a ship's bay in a multi-port transport route, to minimize the total costs of container travel. They proposed a mixed integer programming model (MIP) and an advanced genetic algorithm to solve the problem, to optimize stowage planning with a minimum of total travel costs. The robustness of the proposed algorithm is demonstrated by numerical experiments.

(Parreño et al., 2019) presented an integer programming model for the problem and proposed several sets of valid constraints that bring its LP-relaxation closer to an integer solution. Moreover, it presented a GRASP algorithm that generates stowage plans with a minimal number of unproductive moves in a high percentage of medium and large-size instances. An extended computational analysis had been performed in which, to the best of the authors' knowledge, the efficiency of integer programming models for the problem is tested for the first time. Concerning GRASP, the computational results showed that it performs well on different sized datasets.

(Korach et al, 2019) presented an efficient metaheuristic for the slot planning problem. Matheuristics are algorithms using mathematical programming techniques within a heuristic framework. The method found solutions for 96% of 236 instances based on real stowage plans, 90% of them optimally, with an average optimality gap of 4.34% given a limit of one second per instance. This was an improvement over the results provided by previous works.

(Zhu et al., 2020) used a basic model for the simplified container ship stowage problem. And then, it was extended by incorporating more practical considerations, which were progressively embedded in extensive models for different scenarios. These integer linear programming models aimed to minimize the number of over stows under the restriction of the mechanical factors, the physical structure, and the stowing rules. The experimental results showed that the models had strong scalability for various scenarios.

(Kim et al., 2020) developed an efficient stowage plan of loading and unloading operations for a shipping liner by considering foldable containers and shift cost-sharing and their proposed MIP model achieve shift minimization under the global optimum perspective by eliminating an inessential shift.

(Wu et al., 2021) analyzed the factors affecting the stowage, focused on the study of the composition of intelligent storage system, and provided a safe and reliable idea for the construction of container ship stowage system.

Contribution

The special feature of the presented work is based on the use of a multicriteria method to find the best location of a container in a container ship. Unlike the previously mentioned works (Table 1) operating a single criterion, in the present study, four criteria are used: the container destination, the container weight, the departure date of a container, and the container type.

The contribution consists in proposing a decision support model that helps the operator to make predictions for the management of different types of container storage in a container ship through the use of a multicriteria Electre III method by considering the criteria mentioned above.

The authors note that this work forms part of the research work in the field of decision support systems, optimization, and multicriteria decision applied to transport, (Tahiri & al., 2020) and (Tahiri & al., 2022).

THE PROPOSED MODEL

The presented study addresses the problem of storing different containers in a container ship, which is a process that decides in near real-time the exact location of a container, to achieve efficient unloading of the container ship. In general, the determination of a location must be done to minimize the number of unproductive movements, which can take place when a container located under another container is to be moved. Some constraints must be taken into consideration when loading different containers:

- Containers carrying dangerous goods must be 5 meters from any other dangerous container to minimize risks.
- Refrigerated containers require existing electrical power only in specific positions in the container ship.
- Containers of the same type shall be placed in the same stack.

In the proposed model, the Electre III method has as an input a performance matrix, the subjective parameters, and gives a ranking of alternatives as an output. This model uses a random algorithm for the allocation of containers in a container ship. The authors assume that the container ship is initially empty. This method takes into account four criteria:

Table 1. Comparative Table of Related Work

Authors	The problem addressed and its characteristics	Resolution methods	Key contributions
Avriel & Penn, 1993; Avriel et al., 1998	• The problem of stowage planning for a container ship is presented without taking into consideration the stability of the ship.	• A mathematical model.	• Minimization of the number of displacements.
Wilson & Roach, 2000	• Loading and unloading of containers.	• A Branch and Bound algorithm. • The Taboo search.	• Determination of the optimal location. of normal and specific containers on the ship.
Imai et al., 2002	• Minimization of stowage operations.	• A stowage planning model.	• Determination of the optimal location of containers in the ship while maintaining the stability of the ship (one constraint only).
Imai et al., 2006	• Minimization of stowage operations	• A multiobjective program in integer numbers. • A genetic algorithm.	• Determination of the optimal location of containers in the ship while maintaining the stability of the ship (several constraints).
Sciomachen & Tanfani, 2007	• Minimization of stowage operations.	• A heuristic algorithm.	• Reduce total loading time.
Monaco et al., 2014	• Minimization of the total travel distance and the number of container handlings.	• A mathematical formulation. • A two-phase Tabu search algorithm.	• Determination of the optimal location of containers and the total travel distance.
Araújo et al., 2015	• The problem of planning the stowage of ships.	• A mathematical model. • A hybrid method (metaheuristics and local search heuristics).	• Minimize the number of container movements and ship instability.
Ambrosino et al., 2015	• The Multiport Master Bay Plan Problem.	• A heuristic algorithm.	• Minimize the ship's total berthing time.
Parreño et al., 2016	• The problem of container storage in a container ship.	• A new integer programming formulation. • A greedy randomized adaptive research procedure (GRASP).	• Provide a high-quality solution in one second.
Kroer et al., 2016	• The container storage problem.	• A binary decision diagram. • A DPLL (Davis–Putnam–Logemann–Loveland) solvers.	• Solve simplified instances going beyond a single bay.
Li et al., 2017	• The problem of container ship stowage along the entire Yangtze River route.	• The GRASP algorithm (Greedy Randomized Adaptive Search Procedure). • An evolutionary heuristic strategy algorithm.	• Find high-quality solutions for planning in two seconds.
Zhang et al., 2018	• The problem of planning stowage within a ship's bay in a multi-port transport route.	• A mixed-integer programming model (MIP). • An improved genetic algorithm.	• Minimize total container travel costs.
Parreño et al., 2019	• The multiport container ship stowage problem.	• An integer programming model. • A GRASP algorithm.	• Minimize the number of unproductive moves required in the loading and unloading operations at each port.
Korach et al., 2019	• The slot planning problem.	• A metaheuristic algorithm.	• Optimize container locations.
Zhu et al., 2020	• The container ship stowage problem.	• An integer linear programming model.	• Minimize the number of over stows under the restriction of the mechanical factors, the physical structure, and the stowing rules.
Kim et al., 2020	• The slot planning problem with loading and unloading operations.	• A MIP model.	• Generates an optimal stowage plan
Wu et al., 2021	• The problem of container ship stowage.	• Intelligent stowage system.	• Construction of container ship stowage system.

1. **The container destination:** the container that has a final destination will be loaded first to a stack and load last those containers that have to be unloaded first.
2. **The container weight:** heavier containers are in lower layers and lighter containers in the upper layers.

3. **The departure date of a container:** the container that has an earlier departure date will be loaded first to a stack.
4. **The container type:** each container has a type; the container of the same type will be placed in the same stack.

The proposed decisional model presented for the problem of storing the different containers in a container ship inspired by the proposed model of (Bouamrane, 2006). This proposed decisional model is organized into five distinct phases. Each of these phases includes a set of steps as shown in Figure 1.

Figure 3 gives an overview of the decision-making process adopted in this approach. Upon the arrival of a container, the decision-makers (handling operators) use a multicriteria evaluation to solve the container's storage problem.

The Class Diagram of the Proposed Decision Model

The use of class diagrams is recommended to present the classes and interfaces of the container placement system. The class diagram of this model is composed of three classes called: ship, stack, and container, which are connected by composition links, such as the link between the ship class and the stack class (Figure 4).

Figure 2. The Proposed Decision Model

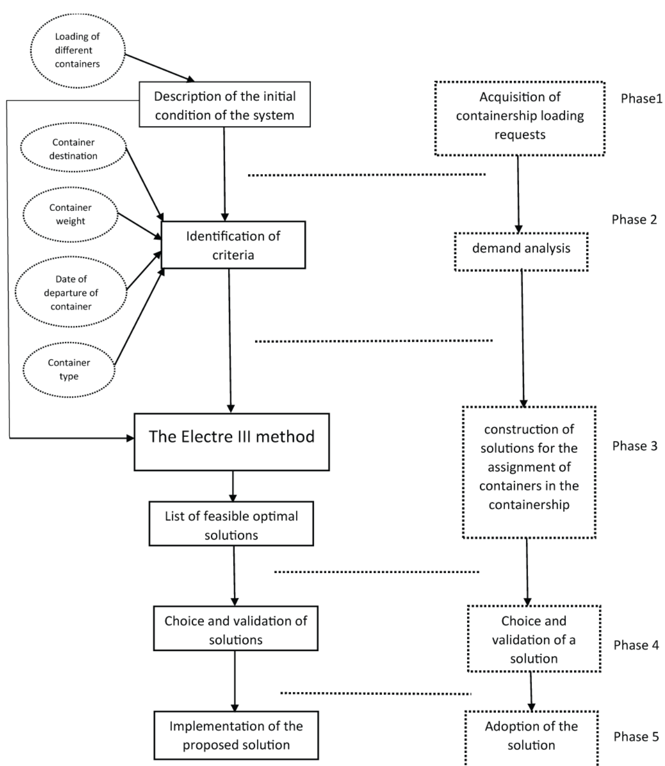


Figure 3. The decision-making process

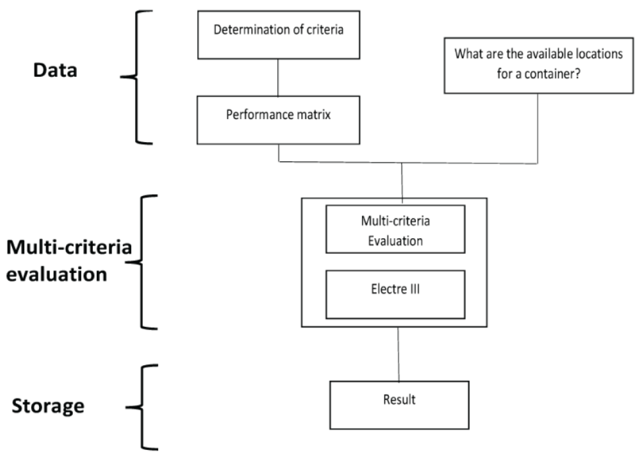
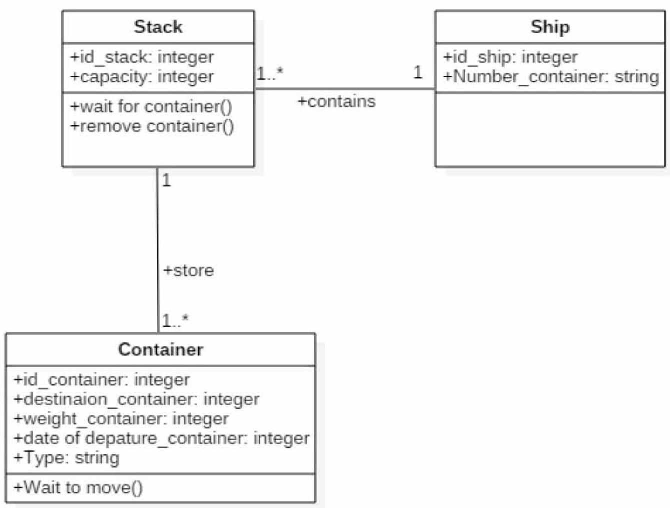


Figure 4. The Class Diagram of the Model



THE ELECTRE III METHOD

The Electre III (Roy, 1978) is a multicriteria method based on the principles of fuzzy logic, allowing to take into account the uncertainties related to calculations and performance evaluation through the use of pseudo-criteria. This is one of the main characteristics of the method to be able to deal with, due to the existence of assessment thresholds, the definition of which is difficult.

The Operating Procedure

In general, Electre III operates in two phases: Aggregation and Exploitation.

The Aggregation Phase

Before the start of treatment of Electre III, the decision-maker is invited to express his subjective parameters, namely Criteria weight, Preference threshold, Indifference threshold, Veto threshold (Roy & Hugonnard, 1982).

To build the overclassification relationships, Electre III uses two principles:

- The principle of concordance.
- The principle of discordance.

The Principle of Concordance

This determines the global concordance index C (a_1, a_2) and requires that the majority of the criteria (taking into account their relative importance) agree with the overclassification relationship. This principle is assured by the following formulas:

$$C(a_1, a_2) = \frac{1}{W}\sum_{j=1}^{r} w_j c_j(a_1, a_2) \quad (1)$$

where:

$$W = \sum_{j=1}^{r} w_j \quad (2)$$

1, if $g_j(a_1) + q_j \geq g_j(a_2)$

$$c_j(a_1, a_2) = 0, \text{ if } g_j(a_1) + p_j \geq g_j(a_2) \quad (3)$$

$$\frac{p_j + g_j(a_1) - g_j(a_2)}{p_j - q_j}$$

otherwise.

Thus:

$$0 \leq c_j(a_1, a_2) \leq 1$$

with:

- a_1 , a_2 : Two different actions.
- w_j : The weight of criterion j.
- g_j (a_1): The evaluation of criterion j for action a_1 .
- j: The index of the criterion.
- p, q: The preference and indifference thresholds respectively.

The Principle of Discordance

This is also known as the principle of respect for the minority. It consists to verify that the minority of the criteria that are contrary to the overclassification relationship is not very opposed to it. The overclassification relationship must not be significantly worse for minority criteria.

This principle is introduced by the following formulas:

0, if $g_j(a_1)+p_j \geq g_j(a_2)$

$$d_j(a_1,a_2)=1, \text{ if } g_j(a_1)+v_j \leq g_j(a_2) \tag{4}$$

$$\frac{g_j(a_2)-g_j(a_1)-p_j}{v_j-p_j}$$

otherwise.

Thus:

$$0 \leq d_j(a_1,a_2) \leq 1$$

with:

- v: The veto thresholds.

Discordance matrices are then realized for each criterion $(d_j(a_1,a_2))$.

Calculation of the Degree of Credibility

The degree of credibility $S\left(a_1,a_2\right)$ measures the strength of the claim that alternative a_1 is at least as good as the alternative a_2. It is determined as follows:

$C(a_1,a_2)$, if $d_j(a_1,a_2) \leq C(a_1,a_2)\, \forall\, j \in J$

$$S\left(a_1,a_2\right)=C(a_1,a_2)*\prod_{j\in J\left(a_1,a_2\right)}\frac{1-d_j(a_1,a_2)}{1-C(a_1,a_2)} \tag{5}$$

otherwise, where J (a_1,a_2) is the set of criteria such that $d_j(a_1,a_2) > C(a_1,a_2)$.

The Exploitation Phase

The ranking algorithm is based on the degree of credibility of each element. One obtains two partial pre-orders that combined provide the overall ranking, according to an algorithm that is described in detail in (Maystre et al., 1994; Roy & Bouyssou, 1993).

Table 2. The Subjective Parameters

	Cr 1: The destination	Cr 2: The weight	Cr 3: The departure date	Cr 4: The type
Indifference	1	1	0,25	0,5
Preference	3	0.5	1	2
Veto	4	3	2	1
Weight	0,4	0,3	0,2	0,1

APPLICATION

Example Scenario

In this section, the authors apply the procedure of the previous section and they take as an example the configuration of the initial state of the following system:

- Stack size: the stack has a capacity of up to 80 containers with 20 containers per floor.
- Total number of stacks: 3.
- Number of containers assigned to the stacks: 20.
- Number of type 1 containers: 9.
- Number of type 2 containers: 5.
- Number of type 3 containers: 6.

Before launching the Electre III algorithm, the decision-maker selects the subjective parameters that must be fixed before the execution of the algorithm because they have significant importance in solving the problem (Table 2).

The identification of the four criteria mentioned previously was made according to their influence on the location of the containers.

The weight represents the relative importance of each criterion. The destination is the most important about the other criteria if for that it has the highest value. The type is the least important so it has the minimum weight.

In Table 3, the performance matrix, shows the values of criteria for each alternative and each criterion.

For the type of container (Cr 4), the authors do a discretization:

- The value 1 means type 1 (Normal container).
- The value 2 means type 2 (Reefer container).
- The value 3 means type 3 (Hazardous container).

Table 4 shows the global concordance matrix C(a,b). It is constructed based on the comparison of the alternatives according to Eqs. (1) and (3).

Table 5 shows the discordance matrix for Cr1 according to Eq. (4).

In this step, the comparison between the concordance and discordance matrices is made, and S (a, b) is determined by Eq. (5). The comparison results are presented in Table 6.

Table 7 shows the Ranking matrix, where P+ if the alternative a_i is better than alternative a_j, I if the alternative a_i is equivalent to alternative a_j, P- if the alternative a_i is as good as to alternative a_j, R if the alternative a_i is incomparable to alternative a_j.

Table 3. The Matrix Performance

	Cr 1	Cr 2	Cr 3	Cr 4
Ct1	5	3	8	1
Ct2	1	6	5	2
Ct3	3	2	7	3
Ct4	8	10	2	1
Ct5	10	3	9	1
Ct6	4	11	3	1
Ct7	2	9	11	2
Ct8	9	1	1	2
Ct9	7	3	15	3
Ct10	15	7	4	3
Ct11	17	8	6	3
Ct12	12	15	12	1
Ct13	18	13	10	1
Ct14	19	12	2	1
Ct15	14	18	17	1
Ct16	15	19	13	1
Ct17	11	14	16	2
Ct18	13	2	7	2
Ct19	5	8	15	3
Ct20	10	10	20	3

Discussion of Results

The results obtained with the application of the multi-criteria analysis model producing the final ranking are discussed. So, the alternatives are ranked in descending order, from the most ranked container for alternative Ct20 to the least ranked alternative Ct1. The alternatives (Ct12, Ct18) have the same rank and have both been ranked in 8th place. The same goes for the alternatives (Ct9, Ct10, Ct14), (Ct3, Ct5), and (Ct2, Ct4, Ct8) all ranked in 9th, 11^{th,} and 12th place respectively.

Figure 5 illustrates the state of the storage area after allocating containers according to the result of the Electre III algorithm.

Container Ct20 is assigned to stack 3 because it is of a hazardous type. The same for the other containers, each container is assigned to its corresponding stack, where stack 1 is for normal containers, stack 2 is for refrigerated containers and stack 3 is for hazardous containers. In the case where there are containers classified in the same rank, if they are of a different type then each container is assigned to its corresponding stack as in the scenario of containers Ct12 and Ct18, otherwise, their departure date is compared, the container with the lowest departure date is assigned first as in the scenario of containers Ct9 and Ct10, the container Ct10 is assigned first because its departure date is lower than that of container Ct9.

Comparison Between the Two Methods Electre II and Electre III

Electre III is similar to Electre II but also adds evaluated outranking relationships and utilizes pseudo criteria, that is attributes that use preference, indifference, and veto thresholds.

Table 4. The Global Concordance Matrix

	Ct1	Ct2	Ct3	Ct4	Ct5	Ct6	Ct7	…	Ct20
Ct1	0.0	0.6667	0.9	0.3	0.4	0.7	0.4667	…	0.0
Ct2	0.4	0.0	0.5667	0.3	0.4	0.3	0.5	…	0.0667
Ct3	0.6	0.7	0.0	0.3	0.4	0.7	0.5	…	0.1
Ct4	0.8	0.7667	0.7	0.0	0.6	0.8	0.7667	…	0.5
Ct5	1.0	0.6667	0.9	0.7	0.0	0.7	0.4667	…	0.4
Ct6	0.8	0.7667	0.7	0.6	0.4	0.0	0.7667	…	0.3
Ct7	0.6	1.0	0.9667	0.6	0.6	0.5	0.0	…	0.3667
Ct8	0.5	0.5	0.7667	0.5	0.5	0.5	0.5	…	0.4667
Ct9	1.0	0.7	1.0	0.7	0.6	0.7	0.7	…	0.1
Ct10	0.8	0.8	0.8	0.7	0.8	0.7	0.5	…	0.5
Ct11	0.8	1.0	0.8	0.7	0.8	0.7	0.8	…	0.5
Ct12	1.0	0.9667	0.9	1.0	1.0	1.0	0.9667	…	0.7
Ct13	1.0	0.9667	0.9	1.0	1.0	1.0	0.7667	…	0.7
Ct14	0.8	0.7667	0.7	1.0	0.8	0.8	0.7667	…	0.7
Ct15	1.0	0.9667	0.9	1.0	1.0	1.0	0.9667	…	0.7
Ct16	1.0	0.9667	0.9	1.0	1.0	1.0	0.9667	…	0.7
Ct17	1.0	1.0	0.9667	1.0	1.0	1.0	1.0	…	0.7667
Ct18	0.8	0.7	0.9667	0.7	0.8	0.7	0.5	…	0.4667
Ct19	1.0	1.0	1.0	0.3	0.6	0.7	1.0	…	0.1
Ct20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	…	0.0

The main difference between Electre II and Electre III is that Electre III is non-compensatory and it incorporates the imprecise and uncertain (fuzzy) nature of the decision-maker. Nevertheless, both methods are used for solving problems where the importance of the criteria can be quantified.

Comparisons of the Results of the Two Methods (Comparative Study)

The authors have implemented the two multi-criteria methods Electre II (Tahiri et al, 2020) and Electre III on the same conditions (same environment) and with the same criteria on the same data.

Table 9 presents the overall results of the two methods and their comparison. It can be seen that 35% of the alternatives are in very different positions, 55% of the alternatives are in close positions and the remaining 10% are in the same positions.

CONCLUSION

In this paper, the authors addressed the problem of container ship loading through the description of a decision model based on a multicriteria Electre III method, while taking into consideration four criteria, as follows: the destination, the weight, the departure date, and the type. The objective of this study is to help decision-makers (handling operators) in identifying the best container locations in the container ship and make a comparison between the results of this method with the result of the Electre II method. The authors aim to further implement other multicriteria methods and to do

Table 5. The Discordance Matrix for Cr 1

	Ct1	Ct2	Ct3	Ct4	Ct5	Ct6	Ct7	…	Ct20
Ct1	0.0	0.0	0.0	0.0	1.0	0.0	0.0	…	1.0
Ct2	1.0	0.0	0.0	1.0	1.0	0.0	0.0	…	1.0
Ct3	0.0	0.0	0.0	1.0	1.0	0.0	0.0	…	1.0
Ct4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct6	0.0	0.0	0.0	1.0	1.0	0.0	0.0	…	1.0
Ct7	0.0	0.0	0.0	1.0	1.0	0.0	0.0	…	1.0
Ct8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct19	0.0	0.0	0.0	0.0	1.0	0.0	0.0	...	1.0
Ct20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0

a comparative study with the results obtained by these two methods and make a simulation of the container storage in the container ship.

Table 6. The Credibility Matrix

	Ct1	Ct2	Ct3	Ct4	Ct5	Ct6	Ct7	…	Ct20
Ct1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct4	0.0	0.0	0.0	0.0	0.0	0.8	0.0	…	0.0
Ct5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct7	0.6	1.0	0.0	0.0	0.0	0.4	0.0	…	0.0
Ct8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct9	1.0	0.0	1.0	0.0	0.6	0.0	0.0	…	0.0
Ct10	0.0	0.8	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct11	0.0	1.0	0.8	0.7	0.0	0.0	0.0	…	0.0
Ct12	1.0	0.0	0.0	1.0	1.0	1.0	0.0	…	0.0
Ct13	1.0	0.0	0.0	1.0	1.0	1.0	0.0	…	0.0
Ct14	0.0	0.0	0.0	1.0	0.0	0.8	0.0	…	0.0
Ct15	1.0	0.0	0.0	1.0	1.0	1.0	0.0	…	0.0
Ct16	1.0	0.0	0.0	1.0	1.0	1.0	0.0	…	0.0
Ct17	1.0	1.0	0.0	1.0	1.0	1.0	1.0	…	0.0
Ct18	0.8	0.0	0.0	0.0	0.0	0.0	0.0	…	0.0
Ct19	1.0	1.0	1.0	0.1714	0.0	0.0	1.0	…	0.0
Ct20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	…	0.0

Table 7. The Ranking Matrix

	Ct1	Ct2	Ct 3	Ct4	Ct5	Ct6	Ct7	Ct8	Ct9	Ct 10	CT 11	Ct 12	Ct 13	Ct 14	Ct 15	Ct 16	Ct 17	Ct 18	Ct 19	Ct 20
Ct1	0	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-
Ct2	P+	0	P-	R	R	P+	P-	I	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-
Ct3	P+	P+	0	R	R	P+	P-	P+	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-
Ct4	P+	R	R	0	P-	R	P-	R	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-
Ct5	P+	R	R	P+	0	P+	P-	R	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-
Ct6	P+	P-	P-	R	P-	0	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-
Ct7	P+	P+	P+	P+	P+	P+	0	P+	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-
Ct8	P+	I	P-	R	R	P+	P-	0	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-	P-
Ct9	P+	P+	P+	P+	P+	P+	P+	P+	0	R	P-	R	P-	R	P-	P-	P-	R	P-	P-
Ct10	P+	P+	P+	P+	P+	P+	P+	P+	R	0	P-	R	P-	I	P-	P-	P-	P-	P-	P-
Ct11	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	0	R	P-	P+	P-	R	P-	P+	R	P-
Ct12	P+	P+	P+	P+	P+	P+	P+	P+	R	R	R	0	P-	R	P-	P-	P-	R	P-	P-
Ct13	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	0	P+	P-	R	P-	P+	P+	P-
Ct14	P+	P+	P+	P+	P+	P+	P+	P+	R	I	P-	R	P-	0	P-	P-	P-	P-	P-	P-
Ct15	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	0	P+	P-	P+	P+	P-
Ct16	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	R	P+	R	P+	P-	0	P-	R	P+	P-
Ct17	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	0	P+	P+	P-
Ct18	P+	P+	P+	P+	P+	P+	P+	P+	R	P+	P-	R	P-	P+	P-	R	P-	0	R	P-
Ct19	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	R	P+	P-	P+	P-	P-	P-	R	0	P-
Ct20	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	P+	0

Table 8. Ranking of Alternative

1st	Ct20
2nd	Ct17
3rd	Ct15
4th	Ct13
5th	Ct16
6th	Ct11
7th	Ct19
8th	Ct12, Ct18
9th	Ct9, Ct10, Ct14
10th	Ct7
11th	Ct3, Ct5
12th	Ct2, Ct4, Ct8
13th	Ct6
14th	Ct1

Figure 5. The Assignment Containers in Their Best Places

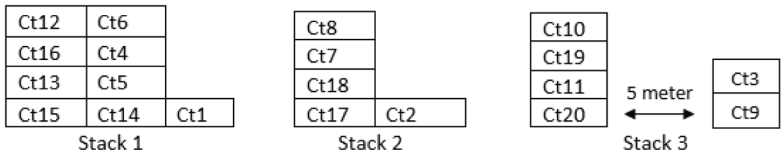


Table 9. Comparison of overall results for Electre II and ELECTRE III

Rangement	Electre II	Electre III
1	Ct16	Ct20
2	Ct13, Ct14, Ct15	Ct17
3	Ct11, Ct12	Ct15
4	Ct10, Ct17	Ct13
5	Ct20	Ct16
6	Ct18	Ct11
7	Ct5	Ct19
8	Ct9	Ct12, Ct18
9	Ct4	Ct9, Ct10, Ct14
10	Ct19	Ct7
11	Ct1	Ct3, Ct5
12	Ct8	Ct2, Ct4, Ct8
13	Ct6	Ct6
14	Ct3, Ct7	Ct1
15	Ct2	
Very different positions		35%
Nearby positions		55%
Position identical		10%

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