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Review

Repositioning and Optimal Re-Allocation of Empty Containers: A Review of Methods, Models, and Applications

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Abstract: Managing empty-container movements is one of the most challenging logistics problems in the shipping field. With the growth of global trade imbalance, the repositioning process has become necessary, immediately after emptying a container. The main contribution of this research paper is to enrich the most frequently used methods, models, and applications in the literature, for relaxing the empty-container-repositioning problem. The article presents practices that vary between organizational policies, technical solutions, and modelling applications. A review of optimization models has been used for comparisons, based on specified criteria, such as the time frame, inputs, outputs, scale of the project, and value. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was applied through the online database Web of Science (WOS). It gives a comprehensive description of all the relevant published documents. On the basis of conducting a brief systematic review, future research opportunities have been determined, considering the emerging phenomena in container transport chains.

Keywords: shipping industry; container-transportation management; empty-container repositioning; optimization methods

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1. Introduction

The shipping industry is considered the primary underpinning of the international economy. It contributes, significantly, to global trade, as it is the most efficient, safe, and friendly transport to move mass goods worldwide [1]. Consequently, more than 90% of world trade is carried by sea. In the middle of the twentieth century, containerization was a significant technological development in the shipping business. It has played an essential role in dramatically reducing the transport cost, which was so expensive before containerization [2]. Song and Dong [3] classified the container transportation chain into two categories: the supply chain of full containers and the supply chain of empty containers. The authors clarified that both supply chains are correlated with each other, as their operations belong to a unified transportation network with the same resources. They explained the container transport chain, since it starts when the shipping company takes empty containers from their depot to be loaded by the consignor. After loading the containers, they are loaded onto a vessel heading to the consignee's destination, either by rail transport or road transport or a combination of both. The laden containers are unloaded at the consignee's store and emptied to be ready for loading, picked up to be returned to empty depots, or returned to shortage ports for future demand [3].

The existence of empty containers in specific ports, terminals, or depots causes an increase in the operational cost. Additionally, it increases the traffic volume, presenting environmental and sustainability problems. Subsequently, decreasing the movement of empty containers does not only have an economic impact but also has an environmental effect; the less empty container movement there is, the less fuel consumption, resulting in reducing the emission of carbon dioxide and congestion. To accurately control the problem, it is necessary to refer to the causes of the emergence of empty-container problems. The significant reason is the global trade imbalance worldwide, where a region characterised by higher imports than exports will face a considerable accumulation of empty containers. In contrast, a region where exports exceed imports will suffer from a shortage of empty containers. Even in the most developed countries, where imports and exports have been almost balanced, empty containers are being accumulated because of the imbalance in the type of containers, especially reefer containers and special equipment.

Table 1 shows the physical flows of containers on the major routes, between 2019 and 2021 [4]. According to UNCTAD 2021, the number of containers moved from Asia to the United States in 2021 was 24.1 million TEUs, while from the United States to Asia was 7.1 million TEUs, meaning that the equivalent of 17 million TEUs had to be repositioned across the Pacific. Similarly, in the Asia–Europe trade route, which faces an imbalance in the return leg, more than half of containership slots leaving Europe are for empties. So, it is not surprising that the shipping lines are trying to be reactive, by performing a repositioning strategy, to meet customer needs and manage container utilization, where every profitable movement of a loaded container generates a non-profitable empty movement [5].

Table 1. Containerised trade on major east–west trade routes, 2019–2021 (million 20 ft).

	Transpacific		**Europe to Asia**		**Transatlantic**	
Year	**Asia–North America**	**North America–Asia**	**Europe–Asia**	**Asia–Europe**	**North America–Europe**	**Europe–America**
2019	19.9	6.8	7.2	17.5	2.9	4.9
2020	20.6	6.9	7.2	16.9	2.8	4.8
2021	24.1	7.1	7.8	18.5	2.8	5.2
Percentage change 2020–2021	17.1	2.7	8.0	9.5	1.4	9.0

The main difficulty in applying a repositioning system is how to efficiently and cost-effectively move empty containers to the proper area, while taking into account various factors. The first factor is the number of empties that should be moved from one area to another. The second factor is the route that should be used to transport empty containers. The third factor is selecting the accurate time, when empty containers become available. Finally, there is the load priority, for loading empty containers in the vessel capacity. In addition to the mentioned factors, the selection of the repositioning scale is another challenge for shipping companies, as they were categorised by Rodrigue et al. [6] as follows: local, regional, and global repositioning. Local-scale occurs when empties move between inland terminals or empty depots and their surrounding areas; it lasts for a short time, with limited use of storage facilities. Regional-scale covers the repositioning of empties among importers, exporters, shippers, consignees, empty depots, and ports around different countries, belonging to one geographic area. Global repositioning is connected with the overseas trade imbalance, to reduce the surplus of empty containers in the ports or depots stocked globally. The authors highlighted that it is necessary to ensure that the hierarchy starts at a local level, before moving to regional and overseas scales [7]. Therefore, the repositioning system is one of the longstanding and ongoing global problems in the transport sector.

Rodrigue et al. [6] state that 56% of a container's life is wasted, stacked at depots, either in order to obtain a future demand or waiting to be placed in shortage areas. Furthermore, the empty-container problem is one of the most significant research areas in the field of the maritime industry, as their movements can generate huge expenditures. According to Epstein et al. [8], managing empty-container movements needs the same expenditure, effort, and time spent on managing loaded containers. Improper management of such a problem may make empty-container costs one of the highest operating costs, after fuel costs. In contrast, the implementation of successful strategies leads to a significant change in the possibilities of transporting goods, on major routes worldwide [9]. Therefore, this paper sheds light on the existing literature about managing empty containers, with the main emphasis on complementing the explanation given in published review papers, to find the appropriate approaches that shipping companies can enhance and apply to overcome their challenges.

The rest of the paper is organised as follows: Section 2 shows the methodology used in this work. Section 3 reviews the approaches to managing the movements of empty containers. In Section 4, the classification of optimization methods based on different scopes of transport networks is identified. It includes a detailed explanation of the most quoted studies in the previous literature. Additionally, it clarifies the role of metaheuristics, in solving the problem of empty-container repositioning. Section 5 summarises the discussion of the systemic review and future research. Finally, conclusions are drawn in Section 6.

2. Research Methodology

To provide a reproducible, transparent, and scientific literature review of empty-container repositioning, Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), suggested by Moher et al. [10], will be performed. It includes a systematic set of steps to find, screen, and include studies for the research to be examined, for transparency and replicability purposes. The search for relevant publications about empty-container repositioning was conducted through the online database Web of Science (WOS), the world's most trusted citation database. The following terms had been used, to identify the maximum number of articles published in this field: empty container* repositioning AND (transport* OR port* OR maritime OR vessel* OR cargo OR mathematical modelling). The authors included the main terms 'empty container*' (capturing 'container' as well as 'containers' by using the asterisk) and included the additional terms in brackets, to narrow down the search to the most relevant papers. The systematic literature search was carried out during May 2021, and the results were, subsequently, updated during December 2021.

The procedure taken to generate a database of all the relevant published documents is visualised in the flowchart in Figure 1. As a result of the initial search through the database, 186 articles and abstracts were nominated. The authors narrowed the research area to find the most relevant papers, by screening the title and abstract as the first process, with 174 articles identified. The selected studies were overviewed quickly, to check for irrelevant papers and studies, with specific keywords like: "empty container reuse, "pricing of empty container", or "emission measurement of empty container". After a strict scanning of the selected papers's introduction, methodology, and conclusion, 124 articles remained and were assessed for eligibility, following this second filtering level. Finally, via a widescreen of the whole paper for the remaining studies in this level, by thoroughly reading the entire document, 6 articles were excluded due to their lack of relevance to the research topic, leaving a total of 118 articles.

The criteria for inclusion and exclusion used are explicitly stated in Table 2. Thus, the authors evaluated the literature eligibility, independently, according to the predefined exclusion and inclusion criteria. The restrictions for document type, language, and subject area were applied before importing the literature in the bibliographic manager. The abstracts and introduction for all studies were evaluated; if the study meets any exclusion reasons, it will be excluded, immediately. Besides, if the abstract of a specific paper is not accessible, the entire paper will be reviewed. Afterwards, full-text evaluation took place, and some articles were excluded, by exclusion reasons. The authors managed all the inconsistencies, regarding the relevance of the reviewed papers, through discussion and consensus. Overall, focusing on the environmental aspects of empty-container movements is one of the main reasons for excluding several studies.

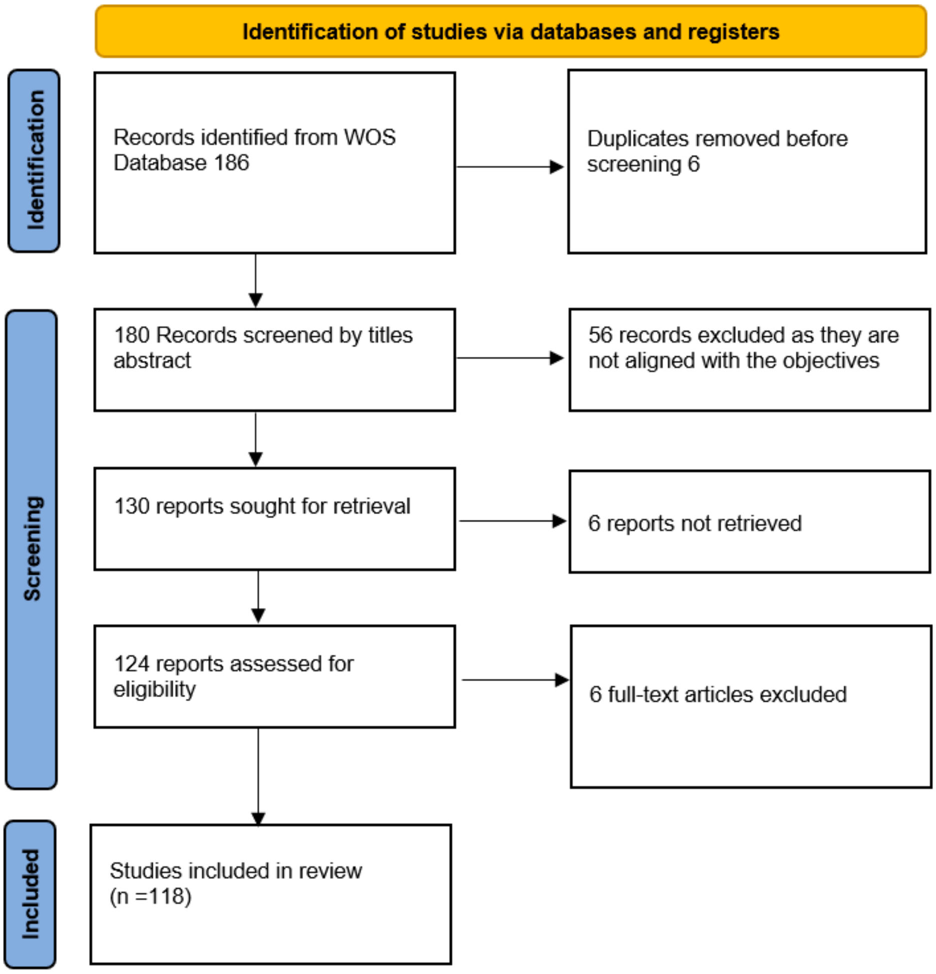

Figure 1. PRISMA flow diagram describing the paper selection process.

Table 2. Inclusion and exclusion criteria.

Selection Criteria	**Scientific Database**	
Inclusion	Peer-reviewed research articles, conference proceedings papers, books, book chapters, review papers, short surveys, and serials mainly discuss the models and methods to solve the empty-container-movements problem.	
Exclusion	Before importation to a bibliographic manager	Non-English publications, articles with missing abstracts, notes, editorials
	During title screening	Generic articles about empty-container movements are used as examples and/or future recommendations.
	During abstract screening	-Not related to the transportation field, e.g., safety management. -Articles address the new technologies of reusing empty containers. -Industry publications where outcomes are not relevant for analysis.
	During full-text screening	-Articles related to the environmental responsibilities and emissions measurement of empty-container movements. -Articles discussed the empty-container repositioning without describing specific applications.

3. Empty-Container Management

Based on the literature overview, all the widely used methods, models, and applications for managing empty-container traffic, are presented in Figure 2. The approaches can be divided into three main perspectives. The first perspective focuses on the organizational solutions performed by shipping companies to reduce the movements of empties, such as container leasing, container substitution, and carriers's collaboration. The second one explains how technological innovations and the new designs of containers, such as the foldable concept, can support the problem of empty containers. The modelling technique is the third perspective, which studies the different methods for managing the repositioning of empty containers.

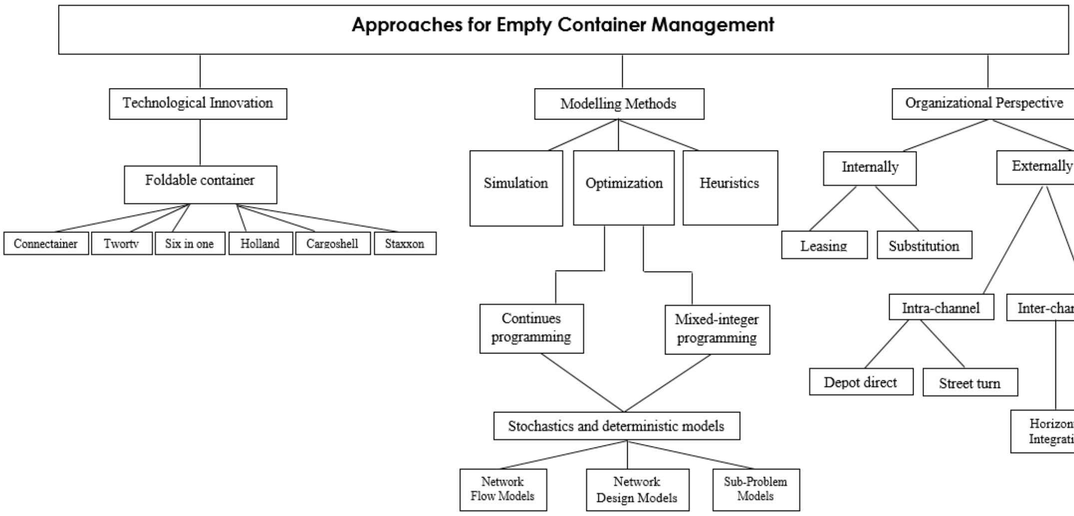

Figure 2. Approaches for solving the empty-container problem, adapted by authors.

3.1. Organizational Logistics Perspective

Shipping line companies often take the whole responsibility for handling the problem of empty-container movements, as they have a larger share of container ownership [11]. Subsequently, they have two internal possibilities for solving the problem:

3.1.1. Internal Solutions

- Container leasing has seen more attention in the past few years, as an approach for managing empty-container traffic. According to Theofanis and Boile [7], leasing arrangements come into three major types: master lease, long-term lease, and short-term lease. The master lease is the type that is most related to the repositioning issue, by hiring containers at places with a shortage and to off-hire containers at surplus points. On the contrary, long- and short-term leases aim to invest their equipment, without any management services provided to the lessee. However, the opportunity for shipping lines to save costs by leasing containers remains linked to the terms and conditions of leasing contracts [12].
- Container substitution is the second internal approach to deal with container fleet imbalance [13]. Due to containers having different types and sizes, the demand for a particular container can be fulfilled by supplying another one [14]. Regarding the size substitution, the demand for two 20 ft empty containers may be replaced by supplying a 40 ft empty container [15]. Additionally, shipping lines can apply type substitution, by exchanging the demand for dry containers by providing a reefer container, without operating the refrigerator. Braekers et al. [16] explained that this strategy is challenging and cannot be a common practice, especially if the customer demand is subjected to some rules and conditions.

3.1.2. External Solutions

The external solution depends, not on implementing the solution internally by one shipping company, but on the cooperation among all stakeholders:

- Intra-channel solutions focus on vertical coordination among the different players in the container-transport chain. There are two proposed strategies for allocating empty containers: depot-direct and street-turn [17]. The idea of depot-direct is to establish a neutral supply point for empty containers to be stored, instead of moving them back to the port. Furthermore, the exporter can get the empty container faster, and the travel time and the repositioning cost will decrease [18]. Street-turn means that shipping companies can use imported containers directly for exporting purposes at the consignee's location [17,19]. Although a street-turn strategy can reduce the total cost and congestion, it needs changing regarding some contract regulations with customers to deal with such reuse, tracking, and tracing of the empties's interchange [20].
- Inter-channel solutions depends on horizontal cooperation [21]. Shipping lines can cooperate in several formats, such as slot exchange, alliances, and resource pooling, while competing in providing shipping services [22,23]. Pool-sharing containers is one of the critical strategies discussed by Theofanis and Boile [7]. They refer to the box-pool attempt, called Grey-Boxes, also known as free-label containers, which aims to reduce shareholders's expenses by cooperating in providing empty containers without possession consideration. Vojdani et al. [24] ensured that such a strategy could decrease the movements of the empty container, store operations and subsequently, the total costs. This strategy did not receive the expected commercial acceptance due to competitiveness and confidentiality.

3.2. Technological Innovation

Over the last decades, technological innovations proved that they could grant valuable solutions to overcome the problem of empty containers. Moon et al. [25] presented different examples of foldable containers, which can reduce the storage space of containers and then reduce the repositioning cost. Six-In-One (SIO) container is a foldable design that is a fully demountable 20 ft container that can be folded, stacked, and interlocked by the exact dimensions of a standard container. Tworty container is another design that consists of joining two containers of 20 ft, to form a 40 ft with the same size, capacity, and dimension. Connectainer has the same idea, regarding the transformation of 40 ft into 20 ft and vice versa, within 30 min [26]. Attempts to create a foldable container did not stop, and many companies intervened to compete with new designs [25], such as Cargoshell, Staxxon container, and 4 FOLD container. Moon et al. [25] stressed that utilizing such new technologies requiring different handling techniques is an arduous task. It can be considered a time-consuming and expensive process in the shipping industry. Especially if the purchasing price of these new containers is too high, compared with the price of the standard container, which is about 3.5 times more expensive. Hence, using the foldable containers would become profitable, when the price of a foldable container becomes half cheaper than the standard container.

3.3. Modelling Approaches

The transportation field has long recognised the power of operation research to manage real-life problems. Hence, a considerable number of influential scientific publications have been focused on modelling the problem of empty containers, whether by optimization, simulation, heuristics, or a hybrid between them [27]. The most critical contributions used to solve the empty container problem are presented in Table 3.

Table 3. Modelling Approaches for Empty Container Problems, adapted by the authors.

Year	Authors	Model	Solution Approach	Description
1998	Cheung and Chen [28]	A two-stage stochastic network	Quasi-gradient method	Evaluating the model over a rolling horizon environment
2002	Choong et al. [29]	Integer programming	Deterministic Dynamic Optimization	A case study of potential container-on-barge operations within the Mississippi River
2005	Olivo et al. [30]	Integer programming	A minimum cost flow problem	A Mediterranean region was examined as a case study by different modes of transportation.
2007	Shintani et al. [31]	Knapsack problem, then network flow problem	Genetic algorithm	Both port and ship-related cost factors were used in a non-linear cost function
2007	Lam et al. [32]	Dynamic stochastic programming	Approximate Dynamic Programming	The cost function is based on multi-port and multi-service system
2007	Wang and Wang [33]	Integer linear programming	LINGO	Inland transportation considers the container shortage and leasing costs
2008	Chang et al. [13]	Container substitution flow problem	Rounding LP-solution, branch and bound and CPLEX	Container substitution allows street turns
2009	Bandeira et al. [34]	Decision support system	LINDO	Mathematical programming techniques, stochastic models, simulation, and heuristic technique was integrated
2009	Di Francesco et al. [35]	Multi-commodity flow problems	Time-extended multi-scenario optimization model	A shipping company located in the Mediterranean region was examined
2009	Dong and Song [36]	Simulation-based Optimization	Genetic Algorithms and Evolutionary Strategies	The model includes multi-vessel, multi-port and multi-voyage shipping systems
2010	Shintani et al. [37]	An integer linear programming model	container flow mode	Foldable containers were considered
2011	Brouer et al. [38]	Relaxed linear multi-commodity flow model	Column generation algorithm	Real-life data from the largest liner shipping company, Maersk
2011	Meng and Wang [39]	Network design problem: mixed-integer linear programming model	CPLEX	Hub and spoke and multi-port-calling operations based on Asia–Europe–Oceania shipping network
2011	Choi et al. [40]	linear programming model	Time-expanded minimum-cost flow problem	Global shipping company in Korea used as a case study
2012	Long et al. [41]	A two-stage stochastic programming model	Sample Average Approximation	Scenario decomposition as considered
2012	Dang et al. [42]	Inventory control problem by the simulation model	Heuristics with genetic algorithm	The perspective of a container depot

Table 3. *Cont.*

Year	Authors	Model	Solution Approach	Description
2012	Dong and Song [11]	Cargo routing problem: Integer programming	Two-stage of shortest path and heuristics for an integer programming	An Asian shipping company with multiple service routes was examined as a case study
2012	Epstein et al. [8]	An inventory model and a multi-commodity network flow model	CPLEX	Consider multiple container types
2013	Moon et al. [25]	Three mathematical models and Two heuristics	A heuristic for an initial solution of small instances by using Lingo and using local search for improvement	Comparing standard and foldable containers based on costs
2013	Di Francesco et al. [43]	A stochastic programming approach	Time-extended multi-scenario/CPLEX	Non-anticipatively conditions were used to link scenarios
2013	Lai [44]	Time-space network	Integrating Branch and Bound with CPLEX for the multiple-scenarios situation	Data uncertainties for empty containers were used, such as capacity, handling, storage and transport
2013	Furio et al. [45]	Min-cost network flow optimization model	Decision Support System (DSS)	The model considered street-turn applications in the hinterland of Valencia
2013	Mittal et al. [46]	A two-stage stochastic programming model	Depot location problem in time horizon/CPLEX	New York/New Jersey port was selected as a case study for the model
2013	Dong et al. [47]	OD-based matrix solutions	Genetic algorithm	Experiments on three shipping service routes operated by three shipping companies
2014	Jansen [48]	Integer programming formulation/The flow network	CPLEX	Solving problems with planning horizons and forecast
2015	Huang et al. [49]	Mixed-integer programming model	CPLEX	A case study: Asia-Europe-Oceania shipping network
2015	Wong et al. [50]	Constrained linear programming	Shipment yield network driven-based model	A case study of service routes of Trans-Pacific trade operated in the G6 alliance
2015	Zheng et al. [51]	Two-stage optimization method	Centralised Optimization then Inverse Optimization	Experiments on an Asia–Europe–Oceania shipping service network
2016	Zheng et al. [52]	Network design: mixed-integer non-linear model	CPLEX	Considered perceived container and leasing prices
2016	Sainz Bernat et al. [53]	Simulation models with metaheuristic	Discrete-event simulation and genetic algorithm	Pollution, repair, and street turns are in the context of model
2016	Akyüz and Lee [54]	Mixed-integer linear programming model	b-column generation and ranch and bound algorithm	Simultaneous service type assignment and container routing problem were solved
2017	Monemi and Gelareh [55]	Integrated modelling framework: mixed-integer linear programming	Branch, Cut and Benders Algorithm (BCB)	The transhipment decision was considered

Table 3. *Cont.*

Year	Authors	Model	Solution Approach	Description
2017	Wang et al. [56]	A revised simplex algorithm	Network flow model	Foldable containers were included
2017	Xie at al. [57]	A game-theoretical: Inventory sharing game	Nash equilibrium	Intermodal transportation system consists of one rail firm and one-liner carrier
2017	Benadada and Razouk [58]	Optimization-simulation	Arena software	A real case study of the container terminal at Tanger Med port was applied
2018	Belayachi et al. [59]	A heuristic method by neighbourhood.	A decision-making/Taboo Search method.	Reverse logistics of containers
2019	Zhang et al. [60]	Two-layer collaborative optimization model	CPLEX and Genetic Algorithm	Combined tactical and operational levels based on business flow
2019	Xing et al. [61]	Simulation-based two-stage Optimization	Dynamic planning horizon and Genetic Algorithm	The quotation-booking process is included in operations decisions
2019	Hosseini and Sahlin [62]	A multi-period uncertainty optimization model	Chance constrained programming	A case study of European logistic service provider
2019	Gusah et al. [63]	Simulation modelling by agent-based modelling	AnyLogic	A case study of Melbourne, Australia
2020	Göçen et al. [64]	Two mathematical programming models	Mixed-integer linear programming and scenario-based stochastic programming	Real data taken from a liner carrier company include different types of containers

4. Review on the Optimization of Empty-Container-Repositioning Techniques

Most models for solving the problem of empty-container-repositioning focus, primarily on optimization, by performing mixed-integer and continuous programming, whether they are deterministic or stochastic models. For more understanding, optimization methods will be presented in the next section, based on the categories referred by Kuzmicz et al. [5]. The authors classified the repositioning problems, according to the scope of the container transport networks: network flow models, network design models, and models under other decision-making constraints. The network flow scope is presented in the first subsection, as discussed extensively in the previous literature. The following part explains the problem based on container-network design, followed by resource constraint models.

4.1. Repositioning by Network Flow Model

The mainstream of network flow models is to generate a set of arc-based matrices. Each element in the matrix has a numerical value representing the number of empty containers that need to be shifted from one node to another on an arc of the shipping network. Many authors addressed the problem in deterministic and stochastic optimization models. In the first group, deterministic models depend on forecasting data using a rolling-horizon fashion. Early literature for the deterministic study was discussed by Florez [65]; the author established a dynamic transhipment network model in line with the leasing strategy. Choong et al. [29] addressed the problem of an intermodal transportation network, explaining how the duration of the planning horizon can affect repositioning decisions. Erera et al. [66] developed a dynamic multi-commodity network flow model, considering container booking and routing decisions. In the same year, Olivo et al. [30] proposed an integer programming model with multiple transport modes in ports and depots (see, also, [11,49]).

Di Francesco et al. [35] proposed a multi-scenario multi-commodity time-extended optimization model. The authors introduced a deterministic model according to the available information of demand and supply values. To clarify their models, they described the system dynamics through a time-space network with a five-period network consisting of five ports, two vessels, and the same type of containers. The deterministic formulation includes inventory decision variables, which refer to the decision made at a specific period on the number of empty containers to be stored in the port. Additionally, the transportation variables indicate the decision made at a particular period on the number of empty containers of type to be moved by vessel from port to port. Another primary variable of their model is the number of empty containers available in port at a specific period to be loaded/unloaded on the vessel. They consider all the related costs where the arrival time is indicated in its schedule. The main constraints can be summarised as follows: the capacity of empty containers number to load, unload, reposition, and store in daily operations; the available number of empty containers inside the port in a given period should be loaded on the following arrival vessels based on port restrictions; the demand for empty containers should be satisfied by past stocks and by unloaded containers from departure vessels; the volume of empty containers that should be stored in a port at specific period should not exceed the storage capacity; and the repositioning process for empty containers between ports cannot exceed the space available on vessels. Hence, the objective function of the deterministic model can be as follows:

$$\begin{aligned}
\min \sum_{t\in T}\sum_{p\in P}\Bigg[& \sum_{v\in V(i,t)}\left(c^{m}_{p,t}(i,j)x^{m}_{p,t}(i,j) + \sum_{i\in\overline{H}} c^{u}_{p,t}(v,i)x^{u}_{p,t}(v,i) + \sum_{i^{d}\in H} c^{u}_{p,t}(v,i^{d})x^{u}_{p,t}(v,i^{d}) \right) \\
& + \sum_{i\in\overline{H}}\left(c^{h}_{p,t}(i)x^{h}_{p,t}(i) + \sum_{v\in V(i,t+1)} c^{l}_{p,t}(i,v)x^{l}_{p,t}(i,v) \right) \\
& + \sum_{i^{d}\in H} c^{h}_{p,t}(i^{d})x^{h}_{p,t}(i^{d}) + \sum_{i^{s}\in H}\sum_{v=1} c^{l}_{p,t}(i^{s},v)x^{l}_{p,t}(i^{s},v) \Bigg]
\end{aligned} \tag{1}$$

The deterministic formulation can give an adequate policy, if the data are accurate and future events are not considered. Therefore, the authors extended their model to adopt a formulation with uncertain parameters. All model parameters are assumed to be specific for a given period, while uncertain parameters can appear in the first period. Based on expert opinions, the authors introduced a compact form for the multi-scenario formulation. To clarify the interest of the model, the authors simulate the system behaviour through several periods and compare the policies of multi-scenario with deterministic ones. The simulation results show that the multi-scenario strategy yields higher operating costs than the deterministic model in each case, while providing an advantage to fulfilling unexpected demands in future periods promptly. Additionally, multi-scenario policies have an option for allocating more empty containers to the area with higher demand.

Such formulations may be pretty insufficient, where the operational environment for decision-making in this field is significantly changeable. Furthermore, the second group is subjected to stochastic factors, as empty containers's supply/demand volume cannot be forecasted, accurately [28,41]. Moreover, the stochastic optimization model describes the demand and supply as uncertain parameters. Crainic et al. [67] were the pioneer researchers, presenting a stochastic model in the land-distribution system. They presented a time-space network flow model, based on a single commodity. The main decision variables of this model describe the following: the number of moving containers from an origin depot to a destination depot; the available number of empty containers in the depot at the end of the horizon; and the total number of allocating empty containers in a specific period to be moved from a current depot or a customer to arrive at new customer or depot. Later on, their work was extended to include the multi-commodity transportation network and substitution strategy. The authors added stock variables and substitution variables to increase the demand response. The authors suggested decomposing the network problems characterised by multi-layer, multi-commodity, linear, and minimum cost network flow problems. They were followed by many authors, among others: [28,68–70].

Lam et al. [32] presented a stochastic dynamic programming model. An approximate approach was applied to solve the proposed model, taking the temporal difference learning into account. Chou et al. [71] discussed the allocation problem of empty containers in a single service route by proposing a Fuzzy Logic Optimization Algorithm (FLOA). The authors used a fuzzy backorder quantity inventory logic, as a first stage to define the number of empties at ports, considering the stochastic of imports and exports. The second stage is a network flow model, as a mathematical optimization programming to determine the empty containers that should be allocated between ports based on the results in stage one. A case study of the trans-pacific liner route in the real world was applied. Long et al. [38] established a two-stage stochastic programming model; stage one depends on deterministic parameters to specify the operation plan for repositioning empty containers, while stage two adjusted the decisions derived from stage one with the probability distribution of random variables. Epstein et al. [8] built an optimization system, by proposing a two-stage solution approach: a multi-commodity multi-period flow model to solve the imbalance issue and an inventory model to determine the safety stock for each node. The network of this model includes the flow of empty containers, without considering the laden-container flow. Hence, the authors stated the decision variables include: the number of each specific type of container, the movement between locations by a particular vessel, the number of loaded/unloaded containers at an area either to or from the vessel at a specific time, and the number of required containers at a particular location. The authors solved their model by using GAMS and CPLEX.

A comprehensive study, introduced by Song and Dong [3], was selected for a profound explanation. They proposed three network flow models. The first model is based on Brouer et al. [38] study; it is a linear integer programming that studied the problem by providing a time-space network flow model with multi-commodity. The network of their model includes: the flow of laden containers, i.e., y^k_{ij}, and empty containers, i.e., x_{ij}, as the demand of customers is deterministic, while values can differ over a given planning horizon. The objective function of this model aims to decrease the lost-sale penalty cost and minimise the total transportation cost of loaded and empty containers. It can be written as:

$$\min_{y^k_{ij},x_{ij}}\left\{\sum_{k\in K}\sum_{(i,j)\in A} C^k_{ij}C^k_{ij} + \sum_{(i,j)\in A} C^e_{ij}x_{ij} + \sum_{k\in K} C^k_p\left[d_k - \sum_{j\in N,i=O_k}\left(y^k_{ij} - y^k_{ji}\right)\right]\right\} \tag{2}$$

Constraint (3) refers to the demand for commodities k that cannot override the volume d_k, and constraint (4) mentions the same quantity of commodities k moving from one node O_k to another D_k. Constraint (5) refers to the flow conservation k at a node m that is neither O_k nor D_k. Constraint (6) mentions the flow balancing of empty and laden container movements at any node. Additionally, constraint (7) indicates that the total number of empty and laden containers does not exceed shipping capacity. The constraint of non-negativity can be expressed in Equation (8);

$$\sum_{j\in N} y^k_{ij} - \sum_{j\in N} y^k_{ji} \le d_k, \mathit{for}\ i = O_k, k\in K; \tag{3}$$

$$\sum_{j\in N} y^k_{ij} - \sum_{j\in N} y^k_{ji} = \sum_{j\in N} y^k_{jm} - \sum_{j\in N} y^k_{mj}, \mathit{for}\ i = O_k, m = D_k, k\in K; \tag{4}$$

$$\sum_{j\in N} y^k_{jm} = \sum_{j\in N} y^k_{mj}, \mathit{for}\ m\in N, m\neq O_k, m\neq D_k, k\in K; \tag{5}$$

$$\sum_{k\in K}\sum_{j\in N} y^k_{ij} + \sum_{j\in N} x_{ij} = \sum_{k\in K}\sum_{j\in N} y^k_{ji} + \sum_{j\in N} x_{ji}, \mathit{for}\ i\in N; \tag{6}$$

$$x_{ij} + \sum_{k \in K} y_{ij}^{k} \leq u(i,j), \, for \; (i,j) \in A; \tag{7}$$

$$y_{ij}^{k} \geq 0, x_{ij} \geq 0, \, for \; k \in K, (i,j) \in A \tag{8}$$

The model formulation is straightforward; it seems a reality, as laden-container movements were considered. The model can manage the changes in demands over various periods as a planning horizon is presented. Hence, the authors used CPLEX to solve the programming model. Despite the advantages of the model, it includes some problems. The objective function does not have the transhipment's associated costs. Hence the model cannot identify the actual path of the moved commodity in the shipping network, where the number of entities is too large in realistic scenarios. All these drawbacks may result in uneconomical solutions and become computationally intractable.

To overcome the difficulties in the first model, Song and Dong [3] introduced their second model, the origin-link based linear programming network flow model. The concept of this model has been implemented in other research for shipping network design and ship deployment problems [72–74]. It considers the associated transhipment costs for both empty and laden containers. Thus, the objective function becomes more comprehensive. It aims to minimise total costs, including loading, unloading, cargo transportation costs, lost-sale penalty, and transhipment costs for empty and laden containers. The decision variables include the laden container flows, i.e., $y_{o,ri}^{l}$, $y_{o,ri}^{u}$, $y_{o,ri}^{f}$, y_{od}, the number of laden containers that are loaded at the port of call; the number of laden containers that are unloaded at the port of call; the number of laden containers that are carried on board from the port of call; and the fulfilled demands from origin to destination port, respectively. Similarly, x_p, $x_{o,ri}^{l}$, $x_{o,ri}^{u}$, $x_{o,ri}^{f}$, denote the decision variables of the empty container flows. The authors introduced the intermediate variables of transhipment for laden container flows y_b^l, y_b^u, y_p^t and the empty container intermediate variables x_b^l, x_b^u, x_p^t. The linear programming model is given by:

$$\begin{aligned} \min_{\substack{y_{od}, y_{o,ri}^{l}, y_{o,ri}^{u}, y_{o,ri}^{f}, y_b^l, y_b^u, y_b^t \\ x_p, x_{o,ri}^{l}, x_{o,ri}^{u}, x_{o,ri}^{f}, x_b^l, x_b^u, x_b^t}} & \left\{ \sum_{p \in P} \left[C_p^l \left(y_p^l + x_p^l \right) + C_p^u \left(y_p^u + x_p^u \right) + C_p^{t,l} y_p^t + C_p^{t,e} x_p^t \right] \right. \\ & + \sum_{r \in R} \sum_{i \in I_r} \left(C_{ri}^l \sum_{o \in P} y_{o,ri}^f + C_{ri}^e \sum_{o \in P} x_{o,ri}^f \right) \\ & \left. + \sum_{o \in P} \sum_{d \in P} C_{od}^p (D_{od} - y_{od}) \right\} \end{aligned} \tag{9}$$

The main limitation can be summarised as follows: the fulfilled demands from a port cannot exceed the customer demands. It is not allowed to unload the laden containers at their original ports. The empty containers will not be unloaded if they originate from a port. Other constraints related to the flow balancing of empty and laden containers were applied in the model. They considered the vessel capacity for each leg on all routes. Song and Dong [3] noticed some shortcomings related to the operational information in the above model, associated with the demurrage costs for transhipment laden and empty containers. The vessel capacity constraints cannot fit the operational planning, due to their dynamic nature. The model, also, follows the constant weekly demands for individual port pairs.

Consequently, a two-stage path-based network-flow model, combined with a heuristic algorithm was formulated. It aims to manage empty and laden containers's movement at the operational level, while being a practical solution for large-scale problems. The first stage introduced a path-based network flow model as a static lower-dimension integer programming model to find the assignment plan of the laden and empty container. This path should be at the least cost regarding; container transportation, customer demand backlog, lifting on/off, and transhipment demurrage costs. The main constraints of this model are that the containers flowing into are equal to the flowing out. All serviced vessels in the same route are similar in size. The total number of laden and empty containers that will be loaded shall not exceed the vessel capacity. The unmet demands in a specific week are backlogged and will be included in the backlog cost. In the second stage, the authors used a set of dynamic decision-making rules, introducing a dynamic system that aims to determine the container flows, considering different periods in the planning horizon, based on a weekly plan from stage one. The dynamic model's variables include the demand variables at original ports, the transhipment-at-port variables, the laden container shipments on vessels, inventory variables at ports, and the empty container-on-vessel variables. After that, Song and Dong [3] implemented the heuristic algorithm based on their previous publication [11], which efficiently determined all the problem variables to manage the stochastics demand and dynamically adjust the repositioning process.

4.2. Repositioning by Network Design

Designing a shipping network is a family of challenging problems, as it consists of various routes for a designated fleet to transport multiple commodities in different ports. Subsequently, researchers studied the design of the liner shipping network problem to consider the issue of empty-container repositioning. To our knowledge, the network design with empty container movement was discussed for the first time by Shintani et al. [31]. They introduced a simplified version of the network design problem for container shipping, considering the repositioning of empty containers. The authors divided the problems into two parts. The lower problem was formulated as a Knapsack problem to determine the optimal calling sequence of ports for a specific group of calling ports. The upper problem is to reduce the Knapsack problem by genetic algorithm and employ the network-flow approach.

Meng and Wang [39] designed a shipping routes network for the problem of the empty container, by presenting a rich mixed-integer programming model. The proposed model examined a realistic case study of Asia–Europe–Oceania shipping. The authors defined the leg flow for empty containers and the segment-based path flow for laden containers. The network design of this model attempts to identify which appropriate shipping line should be selected. Subsequently, knowing the ship-deployment plan followed by the chosen shipping line, the number of containers to be loaded on each deployed ship over a segment, and how empty containers should be repositioned. All the tested instances were solved by using CPLEX. The decision variables include the number of ship-deployment plans, the weekly volume of laden/empty containers transported from port to port, and the weekly volume of laden/empty containers loaded/discharged at the port. The objective function aims to minimise the total operating cost, by satisfying the demand and repositioning the empty containers. It can be expressed as follows:

$$\min F(u) = \sum_{r\in R}\sum_{v\in V_r}\sum_{m\in M_{rv}}\left\{C^{fix}_{rvm}\times n_{rvm} + \sum_{(k,l)\in S_r}\left[y^{kl}_{rvm}\times\left(c^{k}_{v}+c^{l}_{v}\right)\right] + \sum_{i=1}^{N_r}\left[\left(\hat{z}{}^{p_{ri}}_{rvm} + \tilde{z}{}^{p_{ri}}_{rvm}\right)\times c^{P_{ri}}_{v}\right]\right\} \tag{10}$$

where ***u*** denotes the vector of all the decision variables, namely;

$$u = \left(n_{rvm}, x^{pq}_{h}, y^{kl}_{rvm}, f^{P_{ri}P_{rI(i+1,N_r)}}_{rvm}, \hat{z}{}^{p_{ri}}_{rvm}, \tilde{z}{}^{p_{ri}}_{rvm}\right) \tag{11}$$

This model has several constraints: TEUs's demand should be equal to the total number of transported TEUs on all its segment-based paths. The sum number of transported laden containers by all the ship-deployment plans on a segment should be the same total flow of loaded containers in the segment-based paths. The selected shipping line should satisfy all repositioning tasks for empty containers, for any ship-deployment plan considered the maximum berth occupancy time. The loading and discharging quantities determine the berth occupancy time for empty containers. The loading and discharging time are considered, for transporting one laden container by ship-deployment plan on a segment of the shipping line. Any port can be an origin, destination, or both and should be visited at least by one ship-deployment plan. Additionally, it is not allowed to send empty containers in deficit and balance ports; likewise, the surplus and balance ports that should not receive any empty containers. The authors assessed the model's efficiency by using 46 realistic ports. They generated 24 instances donated by three dimensions, respectively: candidate shipping lines set, ship types set, and a set of laden container shipment demand of origin-destination pairs. By comparing different network designs with and without considering empty containers, the computing performance shows that designing a network considering empty containers is recommended in all the test instances, as it could gain significant cost savings [39].

Zheng et al. [51] emphasised that exchanging empty containers among liner carriers reduced the movements of empty containers and, therefore, the repositioning costs. They presented a two-stage optimization method to evaluate the perceived values of empty containers in various ports. A vast network design model is used by performing computational tests on 46 ports in Asia–Europe–Oceania shipping service network. In stage one, the authors focused on the empty container allocation problem by introducing a centralised optimization solution for all related liner carriers. Moreover, they determined the weekly number of empty containers delivered from the surplus port i of the liner carrier $k \in L$ to the deficit port j of the liner carrier $m \in L$. The mathematical programming model denoted by P can be summarised as follows:

$$\min \sum_{k\in L} \sum_{m\in L} \sum_{i\in S_k} \sum_{j\in W_m} \left(\lambda_{ij} \times x_{ij}^{km}\right) \tag{12}$$

Subject to:

$$\sum_{m\in L} \sum_{j\in W_m} x_{ij}^{km} = n_i^k, \forall i \in S_k, \forall k \in L; \tag{13}$$

$$\sum_{k\in L} \sum_{i\in S_k} x_{ij}^{km} = -n_j^m, \forall j \in W_m, \forall m \in L; \tag{14}$$

$$x_{ij}^{km} \geq 0, \forall i \in S_k, \forall j \in W_m, \forall k, m \in L. \tag{15}$$

Constraints (13) and (14) refer to the balance of empty containers after allocating. Constraint (15) is a non-negativity variable. In stage two, the authors aim to find the exchange costs, for empty containers that are paid to liner carriers. They let $\left(\left\{cost_j\right\}\right)$ be the exchange costs of empty containers at the deficit ports, following the optimal solution $\overline{x}$ of the model P. Furthermore, the objective function of the linear programming model (denoted by P^k) for the linear carrier that aims to maximise its profit can be expressed as follows:

$$\max \sum_{m\in L} \sum_{i\in S_k} \sum_{j\in W_m} \left[\left(\left(\cos t_j - \lambda_{ij}\right) \times x_{ij}^{km}\right)\right] \tag{16}$$

Subject to:

$$\sum_{m\in L} \sum_{j\in W_m} x_{ij}^{km} \leq n_i^k, \forall i \in S_k; \tag{17}$$

$$\sum_{i\in S_k} x_{ij}^{kk} \leq -n_j^k, \forall j \in W_k; \tag{18}$$

$$x_{ij}^{km} \geq 0, \forall i \in S_k, \forall j \in W_m, \forall m \in L. \tag{19}$$

Constraints (17) and (18) ensure that it is unnecessary to use all empty containers of liner carriers k to fulfil the deficit ports of shipping carriers k, where some empties can be sent to other shipping carriers. Empty containers will be provided, if it will be profitable for the liner carriers. Subsequently, the strategy of some liner carriers is to keep some empty containers in their surplus depot. The non-negative variable is represented in constraints (19). The authors solved the mixed-integer non-linear model by using CPLEX. Based on the obtained solution in stage one, they determine the perceived container leasing prices at the different ports. Later on, they perturbed the parameters of the objective function for applying the inverse optimization approach. An optimal feasible solution was received after the modification of the objective function. Finally, Zheng et al. [51] used the reduced model's dual and inverse optimization to get the desired prices. In another attempt to minimise the repositioning costs, they extended their work, by including the option of using foldable containers, as a substitute for standard containers, in Zheng et al. [52]. They proved that a foldable substitution strategy could contribute to reducing costs. For more details about their extended work, see [52].

The model of Huang et al. [49] is similar to the previous one by Zheng et al. [51]. The authors introduced variables for linear programming, including the number of a specific type of ship sailing on a particular line, the number of empty containers either loaded or unloaded at a port in a specific way, the number of empty containers moved on a leg, the number of laden containers carried on a segment, and the number of empty containers either loaded or unloaded at a port in a specific way. All previous variables are continuous except the first one related to the number of ships. The objective function of their model is to minimise the total cost of transportation. Flow balancing, capacity, and customer demand are the main constraints. Recently, Monemi and Gelaresh [55], also, applied the Benders decomposition to manage the combined problems of fleet deployment, empty-container repositioning, and network design. They verified their model through real data of a medium-sized shipping line with 830 ports. In 2019, Alfandari et al. [75] discussed the problem of designing network routes on a barge container shipping company. This study aims to maximise the company's profit, by identifying a sequence of calling ports and the size of the fleet between each pair of ports. Therefore, the authors proposed a mixed-integer programming model with two formulations: the first needs arc-variables for modelling empty containers, while the second requires node-variables for handling those empties. The model was solved by using CPLEX to optimize all instances with up to 25 ports in a few seconds.

4.3. Repositioning under Resource Constraints

The problem of empty-container repositioning is connected to different issues in the shipping industry field. Moreover, this classification treats the repositioning of empty containers as a constraint or sub-problem under other decision-making problems. Some authors correlated the container and ship-fleet problem with the empty-container-repositioning issue [73–76], and another group deals with the repositioning problem within dynamic empty-container reuse [13,17]. Combining the idea of purchasing policies as a setup cost with the repositioning problem was discussed by [77–79]. An exciting approach studied the relation between the price competition of the transport market and the repositioning of empty containers [80]. Merging the concept of dry ports with the problem of empty container movement was clarified by [57], as busy seaports with a significant transhipment volume affect the repositioning process. For more descriptions of dry port, see [81]. Finally, many publications studied the empty-container-repositioning problem within shipping service route design [31,39,56,82,83].

Shintani et al. [37] studied the effect of using foldable containers in the hinterland on the repositioning cost of empty containers, by developing five-integer programming models. They introduced a minimum cost multi-commodity network flow model for three different shipping service routes: Asia–Europe, Asia–North America, and Intra-Asia. To obtain the optimal solution, the authors applied the Gurobi solver that offers the results in a reasonable time. They clarified that using standard and combinable containers can minimise related costs, including movements, exploitation, and handling and leasing costs, especially in the case of a long returning distance. Wang [84] discussed the problem of fleet deployment and shipping network design, by proposing a mixed-integer linear programming model, taking into account slot-purchasing, integer number of containers, multi-type containers, empty-container repositioning and ship repositioning. The paper's objective is to determine which elements should be incorporated into tactical planning models and which should not. The author investigated all these elements from theoretical and numerical viewpoints, emphasizing that laden and empty containers should be included in all tactical planning models. For details, the reader is referred to [84].

Contrary to most studies exploring the allocation of empty dry containers, Chao and Chen [85] focused on repositioning empty reefer containers. Most allocation strategies cannot easily be adapted for reefer containers, as their demand should be satisfied precisely. Although reefer containers have a high purchasing cost, the authors showed that moving reefer containers can generate more profit than a dry container. They formulated a time-space model to manage the large scale repositioning problem for reefer containers in a Taiwanese shipping company. Since costs are an essential parameter affecting repositioning decisions, the authors explained the costs covered in the model, including terminal handling charge, carriage, and storage costs. They introduced a single-commodity conceptual time-space network model, then formulated the mathematical model. The main variables refer to the number of containers flowing from node i to node $j(x_{ij})$. The related parameters can be summarised as follows: the number of flowing containers in the network q, the estimated cost per unit for moving a container c_{ij}, the level of container safety stock in the port i at the end of the planning horizon I_{ij}, the expected laden container that should be transported d_{ij}, and the number of available spaces measured by TEUs to move the empties from node i to the node j. The objective function, which aims to minimise the total flow costs over the network, can be formulated as follows:

$$Min \sum_{(i,j)\in A} c_{ij}x_{ij} \tag{20}$$

Subject to:

$$x_{ij} = d_{ij}\ \forall(i,j) \in A_L \tag{21}$$

$$x_{ij} \geq I_{ij}\ \forall(i,j) \in A_T \tag{22}$$

$$x_{ij} \leq u_{ij}\ \forall(i,j) \in A_E \tag{23}$$

$$\sum_{(i,j)\in A} x_{ij} - \sum_{(j,i)\in A} x_{ji} = q, i = s \tag{24}$$

$$\sum_{(i,j)\in A} x_{ij} - \sum_{(j,i)\in A} x_{ji} = -q, i = t \tag{25}$$

$$\sum_{(i,j)\in A} x_{ij} - \sum_{(j,i)\in A} x_{ji} = 0, i = N - S - T \tag{26}$$

$$x_{ij} \geq 0\ \forall(i,j) \in A \tag{27}$$

Regarding the above minimum cost flow problem, constraint (21) guarantees that each voyage should satisfy the demand of laden container movements. Constraint (22) ensures that each port inventory should not exceed the safety level at the end of the planning period. Constraint (23) refers to the maximum space for moving empty containers. Constraint (24) guarantees that the total flows departing from starting node equal the total number of flowing reefer containers into the model. In the same way, constraint (25) ensures that the total number of all containers entering the terminal node is the same number of reefer containers exiting the model. Constraint (26) restricts all incoming flows to be equal to the sum of all outgoing flows for any node in the network, except for the start node and terminal node. The non-negative constraint is considered by constraint (27). Chao and Chen [85] obtained the optimal solution using CPLEX. They compared the actual operation scenario at a global liner shipping company and the scenario output from the proposed model. It shows that the proposed model can improve the quantity of repositioned reefer containers at a low cost in a shorter time.

Wang et al. [56] discussed the issue of ship type decisions, taking into account the empty-container-repositioning problem. The authors aim to design an exact solution approach, for determining the optimal ship type in the shipping route at the tactical level. In addition, they try to find the appropriate time to allocate the foldable and standard empty container at the lowest cost. The authors built a preliminary network flow model that allows standard containers to transport goods, referring to long-term container leasing. After that, they broaden their sub-network to include foldable containers, considering the short-term container leasing. The whole flow network model incorporated the processes of both sub-networks. The solution approach of Wang et al. [56] depends on the iterative procedure; they designed a revised network simplex algorithm. The three main approaches, which support the solution algorithm are: the cycle free property, spanning tree property, and minimum cost-flow optimality conditions. A mixed-integer linear programming model was formulated, based on the result from the previous running. In order to verify the optimality of the model, a CPLEX solver was used on a CMA-CGM shipping line with three real-world shipping service routes. The result clarified that the popularisation of using of foldable containers is highly dependent on the cost of long-term leasing. Subsequently, this study did not encourage the shipping liners to use foldable containers, except under certain circumstances.

4.4. The Use of Metaheuristic Algorithms

All optimization problems mentioned above are often complicated. Furthermore, the use of heuristics/meta-heuristics is essential to alleviate the model's difficulty and make it analytically tractable. Genetic Algorithm (GA), Simulated Annealing (SA), Tabu Search (TS), and Scattered Search are well-known examples that can be considered as general iterative algorithms for the case of solving challanging problems in different domains such as online learning [86], scheduling [87], multi-objective optimization [88], transportation [89], and medicine [90]. Using such algorithms can speed up finding efficient and reliable solutions. Most of these studies showed that a metaheuristic framework can provide valuable insights to the decision makers over a few minutes, which can be considered as satisfactory from the practical perspective. Additionally, Pasha et al. [88] proved that the hybrid metaheuristic algorithms produce better results than their non-hybrid versions. They can be considered as competitive solution approach, in terms of computational time and solution quality. To our knowledge, Genetic algorithm and Tabu search are relatively applied to the problem of repositioning an empty container as follows:

4.4.1. Genetic Algorithm

GA was introduced in 1975 by Holland [91], as a type of global search heuristic. The main idea of GA depends on simulating the natural evolutionary process of speciation and genetics, where it tries to exploit the variations among parent solutions [92]. As referred in Section 3.2, Shintani et al. [31] addressed the design of shipping service networks, taking into account the empty-container-repositioning problem. They used GA, where the optimal route problem was formulated as a location-routing Knapsack problem, to identify the optimal set of calling ports and associated calling sequence of ports. The author designed and modified the genetic representation, provided by Inagaki et al. [93], to adapt their problem. The computational experiments show that the problem with laden and empty distribution can cruise slower due to the efficient empty-container distribution, thus saving fuel costs, considerably. Furthermore, the container shipping network design, without consideration of the empty-container traffic, becomes very costly, due to less efficient empty-container distribution associated with the resulting network [31].

Additionally, Dong and Song [36] presented a simulation-based optimization approach, to address the empty-container-repositioning problem with fleet sizing in a stochastic dynamic model. The authors combined the GA and Evolutionary Strategy (ES) for the optimization approach to find the optimal fleet size and control policy that can minimise the total costs. They formulated the problem as event driven, meaning that when a vessel arrives or departs, the system's state would update. The complexity of the optimization problem prompted researchers to use the simulation-based evolution, for determining the parameters of empty and laden containers that are transported for each port pair at each event by each vessel. The procedures of the method start with initialization, through the stage of selection and recombination, mutation, adjustment, and evaluation via simulation, to the final step of termination criteria that either leads to the best solution or reduces mutation deviation. Additionally, Dong and Song [36] applied an Evolutionary Algorithm-based Policy (EAP) and a Heuristics Repositioning Policy (HRP). They, also, introduced the Non-Repositioning Policy (NRP), as a reference point for quantifying the benefits of two other policies. Two case studies were tested, a trans-pacific shipping service provided by a Chinese shipping line and a Europe–Asia shipping service provided by the Grand Alliance. The numerical experiments for two cases proved that EAP could achieve more cost savings.

4.4.2. Tabu Search

TS is a higher level of a heuristic method proposed by Glover, in 1986 [94]. This method aims to go through all the possible solutions, starting from the initial solution and moving to other neighbours step by step. It can be considered one of the most effective methods to tackle complex problems, by providing solutions very close to optimality. There are a limited number of previous works concerning empty-container repositioning using this method. Sterzik and Kopfer [95] focus on the importance of exchanging empty containers among trucking companies clarifying its influence on minimizing the total transportation cost. The authors simultaneously formulated a mixed-integer programming model considering the vehicle routing and scheduling and the empty-container-repositioning problem. Moreover, the Clarke–Wright savings algorithm and Tabu search heuristic were applied for the Inland Container Transportation (ICT) problem. The authors confirmed that the implementation of the proposed algorithm is characterised by effectiveness and efficiency.

Recently, Belayachi et al. [96] discussed the problem of the imbalanced distribution of containers in the liner-shipping network, with the help of TS. They proposed a marine transportation network, which aims to fulfill the customer demand and maximise the profitability of shipping companies, by optimizing the return cost of empty containers. The author launched the treatment process with two scenarios. The first scenario occurs when the number of available empty containers at the stock port can fulfill the customer demands, and there is no problem in this case. The problem is visible in the second scenario, when the port cannot meet the client's demand. In this case, the authors applied the TS algorithm, to help the ports call the nearest and cheapest empty containers available from the neighbourhood ports, to meet the demand. Meanwhile, the neighbour port would send the required number of empty containers to the shortage port, at a lower cost regarding the distance between each port pair [96]. The authors discussed empty containers's return cost, by comparing the Tabu search method and the random search method. The numerical experiments confirmed that the cost of transporting the empty container without the Tabu search algorithm is more expensive than the process done with Tabu search.

5. Discussion

The main contribution of this research is to investigate a variety of practical approaches to empty-container-repositioning problems in previous studies to determine the appropriate algorithms for future studies. Hence, this search was limited to peer-reviewed research articles, conference proceedings papers, books, book chapters, and review papers written in English without time-frame restrictions, to ensure wider exposure.

A close look at the generated result of this search exposed that 96 out of 118 documents were original research articles, 2 were book chapters, and 20 were conference papers. In terms of geographical coverage, China is taking the lion's share of top empty-container-repositioning research, followed by the USA, England, and Germany. The general trend of researchers's interest, in most countries, is investigating the time progress of developed models for empty-container repositioning over time, to improve the existing results. From the time-coverage perspective, the number of published papers from 1993 to 2021 can be presented in Figure 3, showing that the highest number of publications was recorded in 2013. Overall, the number of publications highlights the awareness and the emergence of a growing academic interest in the problem of repositioning empty containers, among researchers and professionals.

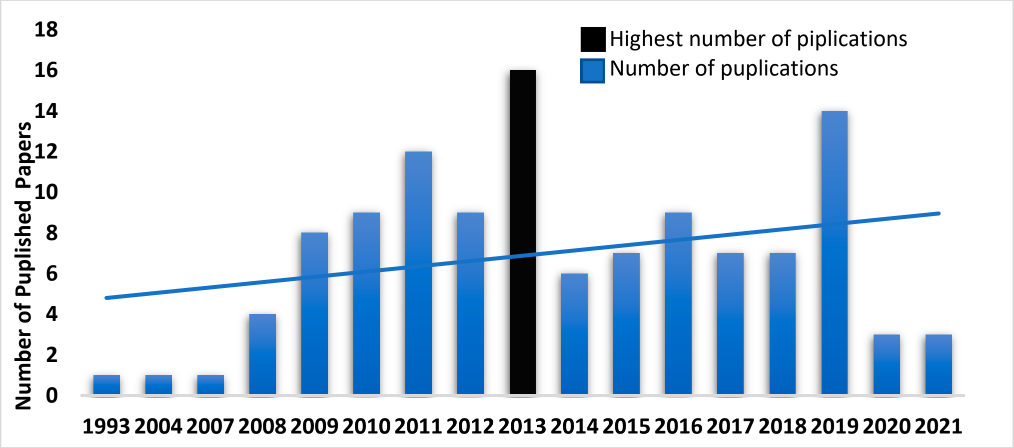

Figure 3. The publication pattern in the field of empty-container repositioning.

From the analysis of the selected literature, over 10 different models were distributed in the most relevant scientific papers about the empty-container-repositioning problem. Hence, the proposed approaches have been used to significantly reduce the movement of empty containers and their total costs, yielding benefits to all shareholders. Some of them are more appropriate for the nature of the problem, such as stochastics optimization models, which are the most utilised in the empty container movement problem. The simulation tool is, also, one of the most practical approaches to managing this problem, with a wide range of scenarios without much adjustment. In this respect, the role of GA to speed up the process of finding solutions cannot be neglectable. It was presented in a significant number of papers presenting the problem of the empty container. On the contrary, the researchers are no longer interested in using deterministic models to solve the current problem, where the method does not consider the future.

Despite all these extensive studies, the research gate is still wide open. A series of insights can be derived to apply a lot of combined models with a flexible tool to tackle the problem of empty-container repositioning. Moreover, future work might extend approaches such as simulation-based optimization, and it can be significantly dedicated to plugging the gap, since a limited number of authors discussed this approach [36,47,58,61,63]. Some robust simulation systems such as Netlogo and AnyLogic that are not used to solve this problem, yet represent an added value in managing this problem. This approach has lacked investigation, although it could become a good attempt in the future to control the suitability of different empty-container repositioning policies in different scenarios.

Apart from comparing the different models for the empty-container-repositioning problem, another direction of future research is to study the situations with multiple means of transportation. Most of the papers listed above raise the problem of empty-container repositioning, from the viewpoint of liner companies and maritime transportation; only a few tackle the problem using trucks, waterways, and rail transportation. Additionally, the different types of containers (e.g., TEU, FEU, dry, reefer) should be considered. The perspective of other actors in the supply chain of empty containers is vitally essential to be discussed within the empty-container-repositioning problem. Considering the anticipated increase in trade volumes and the evolving global trade imbalance, the continuing to propose models will be constantly introduced, as they always represent promising attempts to solve the problem of empty containers.

6. Conclusions

The global trade imbalance among different areas leads to the movement of empty containers from a surplus area to a deficit area where customers demand, leading to high costs and the lack of optimal utilization of the containers. Subsequently, this paper discussed various solutions to manage the problem of empty-container repositioning from different perspectives, including technical solutions, organizational solutions, and modelling techniques. Most researchers face many challenges while addressing the issue, such as containerised distribution, large commercial gateways, uncertainty, data gathering, and coordination problems. Indeed, no researcher considers all these challenges when solving the problem, due to the limiting factor in each model. Hence, future studies can focus on integrating more than one obstacle with each other. Additionally, a hybrid algorithm can be combined to include factors such as uncertainty, travel time, traffic congestion, and demand. On the other side, the development of new technologies, such as foldable containers in the maritime transport sector, influenced the researchers's points of view when designing algorithms and models.

The brief systematic review of the empty-container-repositioning literature led to identifying the models with optimal solutions and enhancing their performance. The models that are not beneficiated in solving the problem would be eliminated. Additionally, models that were not used before were, also, suggested for future research, such as Netlogo and AnyLogic. The systematic review may be extended further in various directions. First, relying on more than one database, to determine the most significant number of studies that are likely to be eligible. Second, using electronic data management, to organise the retrieved information and increase the review's accuracy. Third, comparing and evaluating the proposed approach, against alternative methods for the same factors involved in the problem, in terms of obtaining the optimal solution and processing time.

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