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A Liner Shipping Network Design Problem: A Systematic Literature Review

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ABSTRACT

Maritime transportation is one of the oldest forms of human connection in history, and waterborne transport has always played a crucial role in trade and cultural exchanges. Maritime transport carries more than 90 percent of international trade volumes, especially in worldwide logistics networks. One of the most well-known optimization problems in this area is liner shipping network design. These scheduled transportation lines should be able to satisfy local transportation requests, but also to connect the local market with the major international hubs. There are several studies that have examined the problems that occur in liner shipping. Some of these problems include facility location, network design, etc. The purpose of this study is to find gaps and provide direction for future research in the field of maritime networks. The authors tried to find studies from scientific databases. Some related studies were grouped into type of network, type of problem and solving method based on the characteristic of the studies. Based on the studies that have been reviewed, there are several research possibilities that can be done. Future research possibilities are the integration of liner shipping problems with sustainable supply chains, network design in the liner shipping with a combination of several types of networks, and the application of information integration (physical internet) in network design in liner shipping problems.

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1. Introduction

Freight transportation is among the most vital industries in a modern economy. Volumes to be moved are continuously increasing, as are the expectations of customers in terms of low-cost, high-quality service, and the cost of providing transportation services. Shipping is preferred above other forms of transport, such as truck, aircraft or train, due to for example the low costs, fast speeds and reliable schedules (Meng et al., 2014). Maritime transportation is one of the oldest forms of human connection in history, and waterborne transport has always played a crucial role in trade and cultural exchanges. Nowadays, maritime transport carries more than 90 percent of international trade volumes, especially in worldwide logistics networks (Ducruet, 2020). Over the past three decades, the amount of containerized cargo has increased by more than 8 percent annually, and in 2017, there were more than 5,150 container boats operating globally (Christiansen, 2020).

Within the realm of container shipping, one of the most prominent optimization problems is liner shipping network design. This complex challenge involves designing a network that efficiently connects various ports and routes to facilitate the seamless movement of containers. An interesting insight into the geographical aspect of liner shipping arises from estimates provided by UNESCO. According to their estimates, approximately 60% of the world's population resides within 60 kilometers from coastal regions (Ducruet, 2020). Additionally, efficient port structures make it possible to combine sea transportation with other land-based modes of transportation.

The container traffic has increased from nearly 85 million TEUs (twentyfoot equivalent unit) in 1990 to 651 million TEUs in 2013 with an annual growth rate of 9.3% (Lee & Song, 2017). Containerization has greatly reduced the 2-transport cost and contributed significantly to the global supply chain. Standard containers come in two different sizes, twenty and forty feet, which have given rise to the standard measures of containerised cargo, twenty-foot equivalent units (TEU) and forty-foot equivalent units (FFE). The vessels are operated by shipping companies called carriers, where the largest carriers operate over 600 vessels. As larger vessels are more energy efficient. Based on [3], larger vessels are given more efficiency in the total cost compared to the smaller vessels.

A liner container shipping company operates a fleet of ships deployed on its shipping lines comprising a series of ports to transport containers from one port to another at a regular service frequency. Every 3–6 months, the liner company has to alter its current liner shipping service network and redeploy ships according to the port-to-port container shipment demand forecasted for the next 3–6 months (Huang et al., 2015). To efficiently utilise those very large liner vessels, each region typically has a few larger ports, called hubs, where the liner vessels pick up and deliver containers. From the hubs, the containers are then transported to other ports by smaller, more flexible, so-called feeder vessels. With the development of international trade increasingly, huge vessels are involved in maritime logistics (Zheng & Yang, 2016). The act of transferring containers from one vessel to another in a port is called transhipping. Transhipments occur both between larger vessels and smaller vessels, but also between larger vessels when no suitable service connects the origin and destination hub.

In liner shipping, many containers are often transhipped at the hub ports to benefit from economies of scale on transporting containers through the consolidation of containers. The location of hub ports is a very important problem that significantly affects decision making in container routing and ship routing. In the liner shipping transportation, there are several costs that involved. The major costs for the carriers are vessel acquirement and bunker fuel. However, other costs, like canal fees, port costs and transhipment costs, are also highly significant. Furthermore, an interesting insight into the energy consumption rates of different transportation modes emerges from recent studies. The energy consumption rate of inland waterway transport is approximately 17% and 50% of that of road transport and rail transport (An et al., 2015). The fuel consumption is frequently estimated as a cubic function of the speed, as seen in (Notteboom & Rodrigue, 2008). That research estimated fuel consumption as a function of steaming speed and vessel size.

To improve shipping efficiency, lower transportation costs, and achieve sustainable transportation in the face of fierce competition in the market for shipping companies, it is necessary to make rational and effective decisions to optimize the network of container shipping lines. This leads to the development of the liner ship fleet deployment issue with collaborative transportation (Du et al., 2016). We also need decisions in the liner shipping sector that can guide decision-makers in terms of efficiency and sustainability. Parthibaraj et al. (2018) creates a paradigm that is both efficient and sustainable. Because it establishes variable freight rates and unites market participants with social interests, the concept is referred to be sustainable. Another research included a lot of literature. The research (Vejvar et al., 2020) examines a number ofstudies that relate with the liner shipping industry and focused on the implication of the policy. This literature review is addressed to the researchers who interested and explored about sustainable liner shipping problem. It will guide them to find the existing study and to find the research gap.

2. Methodology

Systematic literature review (SLR), service network design (SND) and liner shipping are the methodologies used in this study. SLR is a methodology to create the literature review, meanwhile SND and liner shipping are the theory to classify the studies. In order to determine what influence the network design in the liner shipping, a SLR was carried out using the search string (service network design OR "SND" AND "maritime" OR "sustainable liner shipping" OR "freight transportation"). Following the procedure of PRISMA (Preferred Reporting Items for Systemic Reviews and Meta-Analysis (PRISMA) is used. Figure 1 presents the processes for the SLR in the present study. The eligibility of literature was bound to peer-reviewed studies published in English from January 2007 to June 2023. The range of date chosen because of the liner shipping is an industry that has existed for a long time. Therefore, the range of date chosen so it could cover the study related but still relate with the current condition. The scholar databases used in this present study were the Scopus database and other sources, such as Google Scholars. The search resulted in 90 articles within the title, abstract, and keywords. The collected articles were checked to eliminate duplicates and articles without full text. The full text of the 72 collected articles was further examined based on the following eligibility criteria, as shown in Table 1.

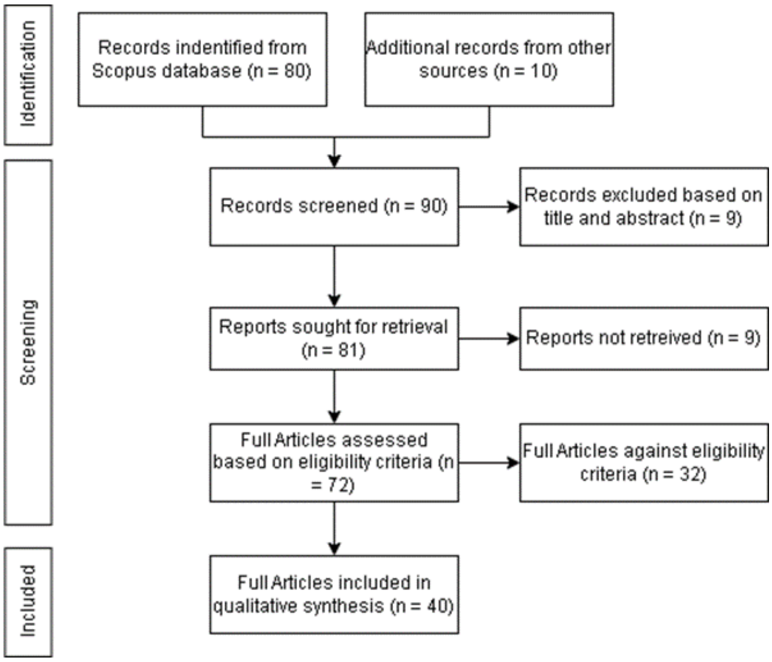

Figure 1. Flow diagram of the SLR stages in the present study

Table 1. Inclusion /exclusion criteria

Inclusion Criteria	Exclusion Criteria
The article was relevant to the objective function	The article was irrelevant to the objective function
The article discussed about service network design	The article discussed about facility location and other irrelevant topics
The article was interested in the maritime transportation	The article was interested in the land and air transportation

To perform this study, a systematic review methodology was used, which resulted in the exclusion of material that did not fulfil the eligibility requirements, resulting 40 studies that were deemed appropriate for further analysis. Each of the publications that were chosen was carefully reviewed, coded, and cross-checked to ensure consistency. A categorization process was carried out to enable deeper insights, depending on the research methodology used in each study as well as the nation of the initial author's institution. The many qualitative, quantitative, and mixed-method approaches used in the study methodologies allowed for a thorough examination of the research issues.

Liner shipping is one of the main possibilities being investigated in this study. Liner shipping is the term for the transportation of cargo on regular scheduled services over predetermined routes, with container ships serving as the main form of transit (Cariou, 2008). Without a doubt, liner shipping is essential to international trade since it makes it possible for commodities to be transported quickly and easily between ports all over the world. The relevance of containerization—a crucial component of this kind of shipping since standardized containers streamline the process of moving goods—was the first important part of liner shipping activities to be explored. The study also covered route network design, in which liner shipping corporations set up permanent routes connecting significant ports all over the world to provide their clients with dependable and consistent services. The importance of port terminal operations was also emphasized because they serve as vital nodes for loading and unloading containers onto ships, significantly streamlining the shipping process.

Moreover, the study sought to explore service network design, a critical facet of supply chain management, particularly in maritime transportation (Crainic, 2000). Service network design encompasses the strategic planning of activities and resources on the supply side of a transportation system, aiming to efficiently meet customer demand while adhering to quality standards and ensuring profitability. The significance of efficient service network design in the liner shipping industry cannot be overstated, as it has the potential to yield substantial cost savings and operational efficiencies. Within the realm of service network design, the study elucidated various activities and their respective importance. One such activity involves facility location, where the optimal locations for key facilities such as ports, terminals, distribution centres, and warehouses are determined, influencing the overall effectiveness of the service network. Route planning was also explored, emphasizing the identification of the most efficient routes and transportation modes for the movement of goods within the network. Furthermore, demand allocation emerged as a crucial aspect, where the allocation of customer demand to appropriate facilities and routes significantly impacts the overall effectiveness of the service network.

It was evident that well-designed service networks provide companies with a competitive advantage in the market. By offering efficient and reliable services, companies can attract and retain customers, differentiate themselves from competitors, and ultimately establish a stronger market position, thereby fostering growth and success in the liner shipping industry.

3. Results

Integration of the supply chain demands cooperation at the organizational and strategic levels. Sharing data and knowledge among supply chains actors is fundamental for an agile flow of goods in response to the customers needs. The success of a seaport depends on the level of integration with the supply chains crossing the seaport (Caldeirinha et al., 2022). The seaport community must create synergies with inland actors such as transport operators, shippers, freight forwarders, and other logistics players. The important role that seaports must play within the framework of supply chains, with an emphasis on the creation of value for customers (Henesey, 2006).

There are mainly two types of studies on the shipping service network design problem, tramp shipping service network design (does not have fixed route and schedule) and liner shipping service network design (have fixed route and schedule) (Christiansen et al., 2004). The existing studies on the liner shipping service network design problem can be classified into two categories – with and without Hub & Spoke. A hub and spoke system are a situation where a central port (hub) and neighbouring ports (spokes) are allowed to move in one direction of delivery and meet at a central location. Designing a liner shipping network is NP-hard, this has been proven by Brouer et al. (2014). There are several studies that discuss this hub & spoke problem, such as a study conducted by Zheng and Yang (2016) taking a case study on the Yangtze River. Because of the Yangtze River's depth downstream, notably between Nanjing and Shanghai, seagoing ships can travel directly to several Asian cities like Busan, South Korea. It features several active potential hub ports. The Yangtze River container transportation network is to be optimized using a mixed-integer linear programming model, according to the authors. Because shipping prices are lower from the upstream to the downstream, a numerical experiment's findings indicate that most feeder ports are assigned to the downstream hubs that are closest to them.

Then a study by Beltran et al. (2023) conducted on the Magdalena River with the application of tree topology, in this work, the graph of hubs is a tree. This work presents a mixed-integer linear programming (MILP) formulation for the HLP with stopovers on a tree topology. Another research done by Zheng et al. (2022) that looks for efficient models to determine hub locations in maritime networks. In this paper, the spatial structure is introduced into the liner shipping hub location problem. They present three effective mixed-integer linear programming models and compare them in the context of container transportation between Asia and Northern Europe considering the impact of the Arctic Sea route. A study by Zheng et al. (2019) discusses hub & spoke if there is a canal around it, in this study the author took an example in the Panama Canal. This study primarily addresses three aspects—canal toll, canal congestion, and ship capacity limitation—to describe the effects of canals, in addition to their geographic position. Based on numerical findings, hub position surrounding a canal is more significantly impacted by ship capacity limitation.

A study from Huang et al. (2015) about liner service network design with considering the laden container routes, fleet deployment, and empty container reposition. This research uses the Asia-Europe-Oceania liner network to evaluate the computing effectiveness and investigate the practical ramifications of the proposed mixed-integer linear programming model. The model can decrease the transit of empty containers and boost ship utilization, according to the results. Also, there is another research from Dang et al. (2012) which deals with the problem of positioning empty containers the operation level, in a port area with multiple depots, Customer demands and returning are assumed to be dependent random variables. Liner network, empty container repositioning and fleet deployment are always considered simultaneously partly. An et al. (2015) solved the combination use of Generation Algorithm and Integer Programming to determine the liner service network design problem with the needed set of liner routes, the calling ports, calling sequence and service frequency of each route, type of the used ships.

An et al. (2015) incorporates the specific natures of inland waterway containers transportation and formulate the inland waterway system containers transportation into a mathematic model with combining genetic algorithm (GA) and Integer programming (IP). For the concurrent design of network and fleet deployment of a deep-sea liner service performed by Gelareh and Pisinger (2011), a study about mixed integer linear programming formulation was proposed. This problem can be simplified by splitting it into a master problem for concurrent network design and deployment and an elastic flow problem as a subproblem. This simplified decomposition is based on the bender decomposition principle. According to the author, this decomposition technique produces the best results in issue resolution. A genetic algorithm (GA) based on the Frank-Wolf method was designed to optimize the network of container liners on the Yangtze River as a result form study, Yang et al. (2014), about network design in rivers. The Yangtze River serves as both a vital link connecting the Midwest Region of Mainland China to the rest of the world and one of China's Golden Waterways for inland water traffic. As seen in Figure 2, the authors consider the forward-backward shipping route. As a result, using mid-size ships in the downstream instead of large ones can not only meet the demand for transportation and raise the loading ratio but also lower the cost of operation.

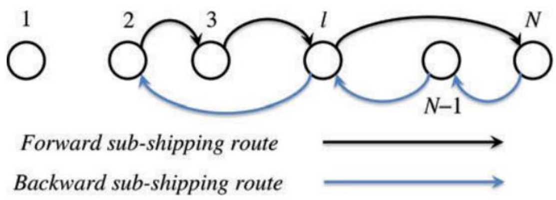

Figure 2. Illustration of Route Composition (Yang et al., 2014)

Research done by Zhao et al. (2018) focuses on the intermodal service network design and, more specifically, the stochastic intermodal service network design (SISND) in a sea-rail network. The authors also consider stochastic travel time, stochastic transfer time, and stochastic container demand. They use a two-stage chance constrained programming model for this problem. A hybrid heuristic algorithm, incorporating sample average approximation and ant colony optimisation, is employed to solve this problem. This paper's case study is on a realistic sea-rail intermodal network from China to Singapore. The result show that the method can effectively improve the performance of intermodal service network design scheme under stochastic conditions and provide managerial insights for decision-makers. Figure 3, show the illustration of a problem with several combination types of transport. With considering this kind of problem, the author could implement it in other combination of transport.

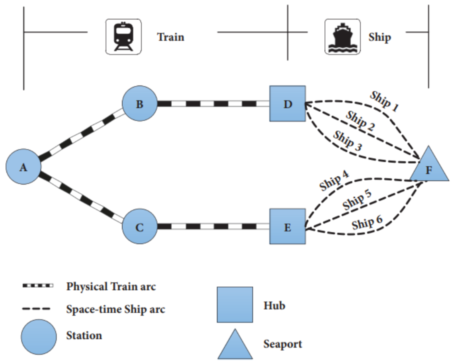

Figure 3. A simple sea-rail intermodal network (Zhao et al., 2018)

A study from Yang et al. (2018) seeks to recreate the network of maritime services between Asia and Europe by considering the expansion of rail services through the New Eurasian Land Bridge and the Budapest–Piraeus line. Bi-level optimization is used to overcome this problem. By substituting the lower-level problem with its Karush-Kuhn-Tucker (KKT) conditions, the study reformulates the suggested bi-level mixed-integer programming model into a single level one. It linearizes the bilinear components of the complimentary slackness constraints to further enhance computational efficiency. This leads to the creation of a mixed-integer linear programming (MILP) model, which is then easier for commercial solvers to solve. The Chinese liner shipping companies COSCO can solve this issue. According to the findings, the new shipping network does not boost ship utilization but could help COSCO increase its profit by 5% to 6%. Discuss how different asset management-related issues can be incorporated into service network design models in Andersen et al. (2009a) and examine how the explicit consideration of asset management-related issues affects the solutions that are produced by these models as well as the corresponding computational effort. Both the arc-based and the cycle-based modeling approaches are used. Then, contrast the various SNDAM model formulations to determine their advantages and disadvantages regarding computational effectiveness. The studies demonstrated how the asset management concerns considered affect the best answers and, generally, raise the amount of computing needed to solve the SNDAM formulation. It's noteworthy to note that formulations based on cycles exhibit a stronger strong linear relaxation than formulations based on arcs.

New optimization model for the tactical design of scheduled service networks for transportation systems where several entities provide service and internal exchanges and coordination with neighboring systems is critical (Andersen et al., 2009b). This research propose a more comprehensive service network design model that improves the integration of vehicle management and service network design with asset management and multiple fleet coordination. The model effectively solved the problem, but the author mentioned to use another method such as column generation to handle more complex and larger instances. When get a complex network, sometimes needs to the effect of different structures ranging from simple ones visiting a port once in a service, to butterfly services where one port can be visited twice in a service and a more general structure where every port in a service can be visited more than once, this research is done by Thun et al. (2017). In this paper, MILP used and solved by a branch-and-price method. The computational study shows that complex service structures can create more cost-efficient networks and that the objective value can be improved by allowing general service structures. A study done by Mulder and Dekker (2014) about liner shipping network design problem with combination of fleet-design, ship-scheduling, and cargo-routing problem with limited availability of ships. The solution method is tested on a problem instance containing 58 ports on the Asia–Europe trade lane of Maersk. The best obtained profit gives an improvement of more than 10% compared to the reference network based on the Maersk network.

There is also a study of Brouer et al. (2014) which discusses network design using metaheuristics and transit time considerations. The model in Brouer et al. (2014) integrates the balancing of empty vehicles, the cost of handling freight in intermediate terminals, the costs associated with moving freight using the selected services, and the penalty costs of not being able to deliver freight. The goal is solving large time-dependent service network design problems with stochastic demand. Then developed a method for finding good solutions to the Stochastic Service Network Design Problem by combining exact and heuristic methods. The heuristic is based on Neighbourhood Search and changes of neighborhood in different phases of the search. While Riessen et al. (2015) developed intermodal container transportation that focuses on the transportation from the seaport terminal to a hinterland terminal, with case study between Rotterdam and several inland terminals in Northwest Europe: The European Gateway Services (EGS) network. The model is formulated as a mixed-integer linear programming problem. The proposed intermodal container network model was able to solve the various experiments fast in most scenarios. Computation times were below 2 minutes, except for the case in which no subcontracts were allowed.

The study of Gelareh et al. (2010) discusses the solution of the network design problem integrated with the hub & spoke problem. This addresses the competition between a newcomer liner service provider and an existing dominating operator, both operating on hub-and-spoke networks. Mixed integer programming (MIP) used and Lagrangian relaxation for solving integer programming problems was proposed to relax complicating constraints by penalizing the objective function and expected to be easier to solve. The conclusion is the model in the present scenario is intended to support decisions at a strategic level the running time are quite satisfactory.

In the pursuit of furthering research on liner shipping network design in the hinterland, recent studies have shed light on promising concepts and methodologies, contributing to the growing body of knowledge in this domain. The chronological exploration of these studies reveals novel insights into the complexities of port service networks and asset positioning, with each investigation leveraging innovative approaches to enhance efficiency and optimize barge transport. Beginning with the work of Ruan et al. (2018), a groundbreaking proposal introduces the concept of a port service network (PSN) comprising a central hub and multiple ports, exemplified through a case study in Zhejiang province, China. This research is driven by the recognition that hubs may face limitations in certain services, and the development of PSNs could unlock the potential for increased economy in barge transport. The model presented by the author employs a mixed-integer nonlinear programming approach, and to address large-scale problems, an optimization algorithm integrated with a genetic algorithm is devised. The study yields valuable managerial insights, offering crucial guidance to government authorities seeking to improve the network's overall efficiency and effectiveness.

Moreover, Pedersen et al. (2009) delves into the exploration of a tabu search metaheuristic as a powerful tool for service network design, particularly concerning asset positioning and utilization, with a focus on constraints related to asset availability at terminals. The research presents mixed-integer programming for both arc and cycle-based formulations of the new model, highlighting the versatility and applicability of the tabu search algorithm in searching through the design vector space. A noteworthy contribution of this research lies in its comparative analysis of the tabu search method against the MIP solver in addressing the service network design problem. The results demonstrate exceptional computational efficiency and solution quality, with the proposed method outperforming the exact MIP solver across the entire spectrum of test problem instances, particularly excelling in handling the largest and most complex scenarios.

In the realm of network design studies, researchers have progressively delved into more comprehensive investigations, incorporating ship scheduling and integration problems to address the complexities of transportation systems. This development has given rise to a series of seminal studies, each unveiling innovative methodologies and fruitful results in the pursuit of heightened efficiency and optimal resource utilization. Commencing this chronological exploration, Agarwal and Ergun (2008) explores network design coupled with ship scheduling, employing exact methods, such as greedy heuristics, column generation, and bender decomposition, to tackle the integration problem at hand. By combining these diverse methods, the study endeavors to yield solutions that effectively optimize ship scheduling within the broader network context. Remarkably, the results reveal a high percentage of ship capacity utilization and a significant number of successful transshipments, pointing towards the efficacy of this integrated approach.

Building upon this integration theme, Koza et al. (2020) and Mueller et al. (2021) delve into the intricate relationship between service network design and scheduling. Both studies propose matheuristics as powerful tools to navigate the complexities of mixed-integer linear programming (MILP) models. Koza et al. (2020) employs matheuristics with column generation, while Mueller et al. (2021) opts for a two-phase matheuristics approach. Recognizing the need for practical applicability, both studies incorporate case studies into their models, enhancing the relevance and real-world impact of their findings. Koza et al. (2020) leverages data from LINER-LIB 2012, while Mueller et al. (2021) analyses the real network of the largest German intermodal rail operators. The outcomes of these studies demonstrate notable enhancements in efficiency and utilization, reinforcing the significance of integrating network design and scheduling considerations. The progressive nature of these research endeavors unveils a growing recognition of the intricacies and interdependencies inherent in transportation systems. By exploring and combining diverse optimization methods, researchers strive to unlock novel solutions that foster efficiency, reduce costs, and enhance overall performance. The application of matheuristics in MILP models showcases the capacity to strike a balance between accuracy and computational efficiency, yielding results that bridge the gap between theoretical rigor and practical applicability.

In our ever-evolving world, characterized by increasing uncertainties, the quest for robust models capable of addressing stochastic problems has gained significant traction. A series of studies (Lo et al., 2013; An & Lo, 2014; Lanza et al., 2021; Wang & Wallace, 2016) have emerged, each contributing unique insights to the domain of stochastic program formulation, paving the way for enhanced decision-making under uncertain conditions. The chronological journey begins with Lo et al. (2013), which introduces a two-phase stochastic program, revolutionizing the handling of stochasticity through the novel concept of regular service reliability. This groundbreaking formulation manifests as a 2-stage mixed-integer stochastic program, primed to effectively address uncertainties and optimize decision outcomes. The practical applicability of this approach is demonstrated through its successful application to the case of ferry network design in Hong Kong, affirming its relevance in real-world scenarios.

Building on the foundation laid by Lo et al. (2013) & An and Lo (2014) advances the frontier of ferry service network design with stochastic demand, incorporating user equilibrium flows. The study devises a cutting-edge service reliability-based network design formulation with recourse, building upon the original formulation presented in Lo et al. (2013). This enhanced model now considers demand uncertainty, user equilibrium flows, and hard capacity constraints, culminating in a versatile and robust approach to optimizing ferry service networks. Once again, the researchers validate the model's effectiveness through a compelling case study in Hong Kong, reaffirming its applicability in practical contexts. Expanding the scope of exploration, Lanza et al. (2021) addresses the stochastic scheduled service network design problem, introducing quality targets and accounting for uncertainty in travel times. The researchers ingeniously harness a 2-stage mixed-integer stochastic program to effectively model the intricate challenges posed by stochasticity. To tackle these complexities, they propose an innovative progressive-hedging-based metaheuristic, rooted in a partial-decomposition concept. This novel approach is crafted with the explicit aim of tackling the challenges intrinsic to stochastic service network design. The results of this study underscore its efficacy, exemplifying how cutting-edge metaheuristic techniques can revolutionize the optimization of service networks in the face of uncertainties.

Lastly, Wang and Wallace (2016) delves into the investigation of the impact of a priori knowledge of spot markets for excess capacity on stochastic service network design problems. Employing a 2-stage mixed-integer stochastic program, this study examines both deterministic and stochastic models, presenting a comparative analysis of the outcomes. This comprehensive examination provides valuable insights into the advantages and limitations of each model type, informing researchers and practitioners alike in their decision-making process. Collectively, these four seminalstudies have laid the groundwork for a sophisticated and robust approach to stochastic program formulation, catering to the complex challenges arising from an uncertain world. The results garnered from each of these studies demonstrate a high level of success, establishing the efficacy of their respective methodologies in addressing stochastic problems.

Also a robust model to solve the transport problem is needed, so that can use it under uncertainty conditions and factors such as the study done by Ng and Lo (2016) & Wang and Qi (2020).To solve problems with larger instances, models that are able to solve these problems are also needed, one of which is the application of methods such as branch and bound as done by Wang et al. (2019). Other methods that can be used to solve the problem are such as the use of hybrid metaheuristics which has been done by Wang et al. (2019). An option about integration is the integration of revenue management considerations into service network design models targeting the tactical planning of intermodal consolidation-based freight transportation carriers, especially for barge transportation done by Bilegan et al. (2022). The study done by Layeb et al. (2018), a new Simulation-Based Optimization Model (SBO-Model) is proposed to solve scheduling problem in stochastic multimodal freight transportation systems. Simulation modelling is used to efficiently account for real stochastic behavior with skewed continuous distributions. Table 2 below summarizes the research that have been read.

Table 2. Literature review

Classification Features		Literature	
		Discuss Sustainability	**Otherwise**
Type of Problem	Hub Location	Beltran et al. (2023)	Zheng & Yang (2016); Zheng et al. (2022); Zheng et al. (2019)
	Network Design	Gelareh et al. (2010); Ruan et al. (2018); Parthibaraj et al. (2018); Du et al. (2016)	Yang et al. (2014); Thun et al. (2017); Mulder & Dekker (2014); Brouer et al. (2014); Agarwal & Ergun (2008); Koza et al. (2020); Lo et al. (2013); An & Lo (2014)
	Service Network Design	Yang et al. (2018); Wang et al. (2019)	Huang et al. (2015); An et al. (2015); Zhao et al. (2018); Andersen et al. (2009a); Andersen et al. (2009b); Riessen et al. (2015); Pedersen et al. (2009); Mueller et al. (2021); Lanza et al. (2021); Wang & Wallace (2016); Ng & Lo (2016); Wang & Qi (2020); Bilegan et al. (2022); Layeb et al. (2018)
Type of Network	Inland Network	Du et al. (2016); Parthibaraj et al. (2018); Gelareh et al. (2010); Yang et al. (2018)	Huang et al. (2015); An et al. (2015); Zheng et al. (2022); Zheng et al. (2019); Zhao et al. (2018); Andersen et al. (2009a); Thun et al. (2017); Andersen et al. (2009b); Mulder & Dekker (2014); Brouer et al. (2014); Riessen et al. (2015); Pedersen et al. (2009); Agarwal & Ergun (2008); Koza et al. (2020); Lo et al. (2013); An & Lo (2014); Mueller et al. (2021); Lanza et al. (2021); Wang & Wallace (2016); Ng & Lo (2016); Wang & Qi (2020); Bilegan et al. (2022); Layeb et al. (2018); Wang et al. (2019)
	Hinterland Network	Ruan et al. (2018); Beltran et al. (2023)	Zheng & Yang (2016); Yang et al. (2018); Mueller et al. (2021)
Solving Method	Exact Method/ Solver	Du et al. (2016); Parthibaraj et al. (2018); Beltran et al. (2023); Yang et al. (2018); Gelareh et al. (2010)	Zheng & Yang (2016); Zheng et al. (2022); Andersen et al. (2009a); Andersen et al. (2009b); Thun et al. (2017); Mulder & Dekker (2014); Riessen et al. (2015); Agarwal & Ergun (2008); Koza et al. (2020); Mueller et al. (2021); Lo et al. (2013); An & Lo (2014); Lanza et al. (2021); Wang & Wallace (2016); Ng & Lo (2016); Wang & Qi (2020); Bilegan et al. (2022); Wang et al. (2019)
	Heuristics/ metaheuristic	Ruan et al. (2018)	An et al. (2015); Zheng et al. (2019); Yang et al. (2014); Zhao et al. (2018); Brouer et al. (2014); Pedersen et al. (2009); Wang et al. (2019); Layeb et al. (2018)

From severalstudies that found and have read, studies that discuss service network design located in river (hinterland) and sea (inland) networks are found with various optimisation problems. As shown in the Table 2, some of these studies discuss service network design in river networks (Zheng & Yang, 2016; Ruan et al., 2018; Mueller et al., 2021; Beltran et al., 2023; Yang et al., 2014) and some of these studies discuss service network design in sea networks (Brouer et al., 2014; Gelareh et al., 2010; Huang et al., 2015; An et al., 2015; Zhao et al., 2018; Thun et al., 2017; Riessen et al., 2015; Agarwal & Ergun, 2008; Koza et al., 2020; Fontes & Goncalves, 2017; Lo et al., 2013; Lanza et al., 2021; Wang & Wallace, 2016; Yang et al., 2018; An & Lo, 2014; Ng & Lo, 2016; Wang & Qi, 2020; Wang et al., 2019; Wang et al., 2019; Bilegan et al., 2022; Layeb et al., 2018; Zheng et al., 2019; Zheng et al., 2022; Andersen et al., 2009a; Andersen et al., 2009b; Mulder & Dekker, 2014; Pedersen et al., 2009). From those studies are classified into research with discussion of sustainability and no discussion of sustainability. The research with discussion of sustainability is still possible to improve and explored.

4. Discussions and Future Direction

The liner shipping problem holds significant importance as it plays a crucial role in shaping the global supply chain and facilitating the efficient flow of goods worldwide. Within the domain of liner shipping, there are various intriguing aspects to explore, as discussed in the previous section, including facility location, network design, and service network design, among others. For instance, researchers have delved into facility location challenges, exemplified by studies on determining hub and spoke locations in both river and sea networks, as showcased by the works of Zheng and Yang (2016) & Beltran et al. (2023) (river network) and Zheng et al. (2019) & Zheng et al. (2022) (sea network), respectively.

As the literature in this field continues to be explored and reviewed, it offers insights into potential research directions for the future. One such direction involves addressing liner shipping problems, such as facility location and service network design, within the context of sustainable supply chain and logistics. Emphasizing sustainability in liner shipping operations can lead to reduced environmental impacts and more eco-friendly transportation practices, aligning with the growing global focus on sustainability.

Additionally, researchers can explore the possibilities of solving facility location and service network design challenges by integrating two different networks. For instance, considering a combination of river and sea networks could lead to novel and more efficient logistics solutions, leveraging the advantages of each network to optimize transportation routes and enhance overall system performance.

Another promising space for future work is the application of information integration and sharing solutions in liner shipping. As seen in Oscar's research on the physical internet, innovative information sharing strategies and collaborative logistics models can significantly improve the efficiency and effectiveness of liner shipping operations. Leveraging emerging technologies and data-driven approaches can lead to enhanced coordination, visibility, and responsiveness in the liner shipping industry.

In conclusion, the liner shipping problem holds a central position in the global supply chain and the movement of goods. Exploring various aspects of liner shipping, such as facility location and network design, presents valuable insights for researchers and industry professionals alike. Future research in this field could be directed towards sustainable solutions, combining different networks, and embracing information integration and sharing approaches. By addressing these challenges, the liner shipping industry can continue to evolve and adapt to meet the demands of an ever-changing and interconnected world.

5. Conclusion

This comprehensive research delves into the application of liner shipping problem within the context of sustainable supply chain and logistics, drawing insights from recent literature. The analysis process entails a meticulous classification based on three key criteria: (1) Type of problem, (2) Type of network, and (3) Solving method. By adopting this systematic approach, the review sheds light on the critical aspects of liner shipping's role in fostering sustainability and integration in the rapidly evolving global landscape.

As sustainability becomes an increasingly paramount concern, and with a surge in the volume of relevant literature, the research recognizes the need to explore promising avenues for future research. Taking these factors into account, the study puts forth a compelling direction for future investigations, with a focus on three specific areas:

1. Sustainable Facility Location and Service Network Design Problems: Given the growing emphasis on eco-conscious practices, research endeavors in this domain should center around devising solutions that align with environmentally friendly principles. Addressing facility location and service network design through a green lens holds tremendous potential for creating sustainable supply chain and logistics systems. Such innovations can pave the way for reduced carbon footprints, resource optimization, and enhanced overall efficiency.
2. Facility Location and Service Network Design Problems in Combination with Waterways Network: Recognizing the significance of waterways as a viable mode of transportation, exploring the integration of facility location and service network design with waterways network emerges as a promising avenue for research. This intermodal approach could unlock newfound efficiencies, capitalize on the advantages of waterborne transportation, and contribute to overall sustainability objectives.
3. Facility Location and Service Network Design Problems with Integration and Sharing of Information: In today's digitally connected world, the power of information integration and sharing cannot be overstated.

Consequently, future research should explore the potential benefits of incorporating this aspect into facility location and service network design problems. By leveraging real-time data, advanced analytics, and collaborative platforms, supply chain and logistics systems can attain heightened responsiveness, improved decision-making capabilities, and enhanced overall performance.

By proposing these three key areas for future exploration, the research seeks to contribute to the ongoing discourse on sustainable supply chain and logistics. The synthesis of recent literature and the identification of these research directions lay the foundation for researchers, practitioners, and policymakers to collectively advance the field towards a sustainable, more integrated, and efficient future.

In conclusion, this research provides a comprehensive review of the application of liner shipping problem for sustainable supply chain and logistics, categorizing relevant literature based on critical criteria. Building on the insights gleaned from this analysis, the study charts a course for future research, proposing three distinct areas of investigation. Embracing these research directions holds immense promise in shaping a more sustainable, integrated, and technologically advanced landscape for supply chain and logistics systems. As the world strives to address pressing environmental challenges and optimize global trade networks, the exploration of these avenues will undoubtedly pave the way for transformative advancements in the domain of liner shipping and beyond.

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