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Assessing the eco-efficiency benefits of empty container repositioning strategies via dry ports

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ABSTRACT

Trade imbalances and global disturbances generate mismatches in the supply and demand of empty containers (ECs) that elevate the need for empty container repositioning (ECR). This research investigated dry ports as a potential means to minimize EC movements, and thus reduce costs and emissions. We assessed the environmental and economic effects of two ECR strategies via dry ports—street turns and extended free temporary storage—considering different scenarios of collaboration between shipping lines with different levels of container substitution. A multi-paradigm simulation combined agent-based and discrete-event modelling to represent flows and estimate kilometers travelled, CO_2 emissions, and costs resulting from combinations of ECR strategies and scenarios. Full ownership container substitution combined with extended free temporary storage at the dry port (FTDP) most improved ECR metrics, despite implementation challenges. Our results may be instrumental in increasing shipping lines' collaboration while reducing environmental impacts in up to 32 % of the inland ECR emissions.

1. Introduction

Containerized transport represents not only approximately 16 % of the total tonnage transported by sea but also around 60 % of the total value of all international trade (Organisation for Economic Co-operation and Development–European Union Intellectual Property Office, 2021). Load unit standardization provided by containerized transport has contributed heavily to its popularity among traders and its increased adoption in different industries since its invention. Although containerized transport has been the backbone of globalization, it has also accentuated one of globalization's downsides: trade imbalance. The asymmetric nature of global trade has long meant an abundance of empty containers (ECs) at some ports but shortages of them at others (di Francesco et al., 2013; Xie et al., 2017). In 2016, for example, 24.6 % of all containers moved by sea were empty (Drewry, 2017). Partly due to flow imbalances, location mismatches between container providers (e.g., ports, dry ports, and inland depots) and shippers, container type mismatches, and timing mismatches, inland empty container repositioning (ECR) has accounted for 50–70 % of all container movements in some contexts (Braekers et al., 2011).

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ECR has direct and indirect costs. On the one hand, its direct costs include transport, handling, storing, and administrative costs, along with CO2 emissions and energy consumption from transport and the storage of ECs. In 2009, the estimated cost of seaborne ECR was approximately US $20 billion and reached up to $30.1 billion when inland ECR was considered, which represents 19 % of the liner shipping market (United Nations Conference on Trade and Development, 2011). From an environmental standpoint, according to the International Maritime Organization (2021), considering proportion of ECR to total container movements, ECR was responsible for 58 million tons of CO2 equivalent worldwide in 2018—that is, approximately 1 % of all global CO2 emissions. As for energy consumption, EC movements consumed 16 million tons of HFO-equivalent fuel—7 % of the whole shipping industry—in 2018. In response to those direct costs, Tao and Wu (2021) have suggested further policy measures to reduce the running of ECs in view of the estimated energy intensity of inland container movements in China's Yiwu–Ningbo region. On the other hand, indirect costs from ECR refer to the effects of container shortages, for example, that generate supply chain disruptions, economic losses, and global flow imbalances. For a recent example, container shortages during the COVID-19 pandemic were a root cause of increases in container rates that peaked at 243 % (United Nations Conference on Trade and Development, 2021).

Practitioners and researchers have theorized potential solutions to improve containerized transport's efficiency by reducing EC trips and increasing the use of more energy-efficient transport modes (Theofanis *et al.,* 2009). Those solutions commonly focus on nuances in geographical scope between the global and the regional—that is, maritime and inland transport, respectively—and implications at each level of the planning horizon: the long, mid-, and short term (Choong et al., 2002). Different measures are introduced to reduce ECR, such as collaboration between actors (Song and Dong, 2015) by using internet-based systems (Braekers et al., 2011) or offering flexibility in free-time durations, grey boxes (Boile et al., 2004) meaning unbranded containers, foldable containers (Konings, 2005), tworty (twenty + forty) boxes (Malchow, 2015) or connectainers (Kuzmicz and Pesch, 2019), container leasing, street turns[1] with or without inland depots (Fazi et al., 2023) and container substitution[2] (Braekers et al., 2011). Along with using inland transportation infrastructure, collaboration schemes provide solutions to further reduce EC movements (Caballini et al., 2016). Hence, combining street turns with inland transportation infrastructure such as dry ports, under collaboration schemes that facilitate container substitution is expected to reduce redundant ECR movements.

Although the benefits of such strategies seem evident, quantifying reductions in ECR costs has been challenging due to lack of data and modeling complexities in dealing with stochastic, dynamic, multi-commodity, and collaboration-oriented systems (Abdelshafie et al., 2022). In a recent contribution, Song and Dong (2022) compile the different modeling approaches to ECR problem and show the different methods to address the complexity inherent in the system. On the other hand, although several researchers have approached ECR from a global angle that overlooks inland ECR using multimodal transport solutions despite their potential to reduce ECR's direct and indirect costs (Braekers et al., 2011), other research suggests that combining intermodal transport with the use of inland port infrastructure can reduce transport costs and times as well as improve container management functions (Roso, 2007; Rodrigue et al., 2010; Nguyen et al., 2021). To address the management of ECs, research on formal methods for systems modeling and impacts assessment that takes multiple measures into consideration together with inland transportation infrastructure is needed (Braekers et al., 2011). Quantifying the costs and benefits of such ECR strategies would not only contribute to the modelling and impact assessment requirements in the literature but also encourage action in the liner shipping industry toward intensifying collaboration in a bid to reduce ECR.

Departing from that discussion, in our research we sought to assess the environmental and economic benefits of ECR operations at dry ports and, in the process, address two major issues in ECR research: studying ECR in combination with dry port and inland port infrastructure and quantifying such solutions. To that end, we selected two ECR strategies using dry ports—street turns and extended free temporary storage—to examine in scenarios of collaboration between shipping lines with different levels of container substitution. Both strategies were chosen given their likely feasibility and acceptance by the multiple actors involved in ECR (Hellekant and Rudal, 2021). We operationalized the purpose of our study in three research questions:

1. What are the environmental and economic benefits of ECR using street turns at dry ports?
2. What are the environmental and economic benefits of ECR using extended free temporary storage at dry ports?
3. How do the outcomes of those two strategies differ in scenarios with varying degrees of collaboration between shipping lines?

To answer those research questions, we proposed a multi-paradigm simulation approach combining agent-based and discrete-event simulation modeling to represent the stochastic, dynamic, and multi-commodity elements of a case in Sweden. Probability distributions were used to model EC demand based on inland container movements in 2019–2021 in the case study. Simulation outputs—kilometers traveled, CO_2 emissions, and cost—were fed into comparisons of the impacts of ECR strategies and collaboration schemes on ECR metrics. By reporting and discussing our research, this paper contributes to closing the gap in modeling intermodal transport in inland ECR, particularly by modeling rail and truck services as individual agents that intervene at predetermined segments of the supply chain.

The rest of the paper is structured as follows. Section 2 describes ECR with reference to the literature, as well as our reasoning behind selecting certain ECR strategies to examine. Section 3 introduces the case and our method, after which Section 4 presents and discusses our findings. Section 5 concludes with a discussion of the findings in relation to the literature and provides implications for practitioners.

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[1] A *street turn*, also called "triangulation" in practice, is the direct deployment of an EC from an importer's facility to an exporter's facility.

[2] *Container substitution* refers to the interchangeable use of container types, brands, and sizes.

2. ECR in liner shipping

Song and Dong (2012) have divided the literature on ECR into three major tracks: seaborne shipping networks, inland or intermodal transportation networks, and ECR as a problem filed under other decision-making criteria. Work in the first track focuses on a specific trade and aims to find cost-effective models to reposition ECs between selected geographical areas (e.g., Feng and Chang, 2008). Some such studies have focused on characteristics of shipping networks, including the hub-and-spoke network design (Imai et al., 2009), or existence of different service networks (Meng and Wang, 2011a, 2011b). Meanwhile, others have combined laden container shipping and liner shipping optimization problems with ECR (Shintani et al., 2007; Song and Dong, 2013; Song and Xu, 2012) in modeling optimized solutions. Collaboration between shipping lines has attracted recent attention within this track as well and provided positive results for individual shipping lines (Du et al., 2021).

In the second track, studies have focused on ECR problems within the hinterland of specific ports (Olivo et al., 2005). Most of those studies have involved modeling ECR problems within intermodal transportation networks (Erera et al., 2005; Bandeira et al., 2009) and even considered seaport–dry port connections therein (Xie et al., 2017; Luo and Chang, 2019). Recently, Cai et al (2022) studied the optimization of ECR between public hinterlands and regional port clusters. In an earlier study, Cai et al (2019) combined seaport-hinterland connections with liner carrier cooperation and extended free detention time and found that liner carriers can compensate for their ECR costs through applying high detention charges. From other perspectives, Kolar et al. (2018) have investigated the dynamics of landlocked hinterlands and challenged the assumptions of ECR models in current intermodal transportation networks. Lopez (2003), meanwhile, has analyzed different ways of organizing ECR between liner carriers and intermodal transport operators in the United States. In an extensive review, Braekers et al. (2011) have also emphasized the need for designing physical and service networks with ECR decisions in multimodal contexts.

Literature in the third track, by contrast, treats ECR as a problem of other liner shipping decisions. Jula et al. (2006), for instance, have combined EC reuse with ECR, while others have focused on designing liner service routes (Imai et al., 2009), ship fleet planning (Monemi and Gelareh, 2017; Meng and Wang, 2011a, 2011b), container fleet sizing (Dong and Song, 2009), and pricing in transport markets (Lu et al., 2020; Zhou and Lee, 2009), more recently, service contract design by ocean carriers (Yang et al., 2021). Wong et al. (2015) have developed a model based on shipment yields which considers that shipping lines prefer to position ECs for higher-paying cargo. Added to that, Zheng et al. (2015) have studied the potential impacts of EC exchange among liner carriers and found that coordination among carriers in repositioning ECs was able to optimally solve the problem as long as repositioning provided profit and value to involved actors.

The third track can be extended to technology and design-related decisions. Recent research addresses foldable containers as a potential solution to reduce the cost and increase the efficiency of ECR. Zhang *et al* (2020) study how foldable containers can solve the ECR problem by using inland waterway transportation. Similarly Lee and Moon (2020) propose a model for robust ECR with foldable containers under uncertain demand. Erdoğan and Kabadurmuş (2020) investigate the impacts of foldable containers as well as street turns and depot-direct strategies on total ECR costs and find out that both street turns and foldable containers reduce ECR cost but depot direct creates other advantages such as adding buffer capacity by acting as a supply point.

Contributing to the second track, this paper investigates an inland physical setting served by a dry port. Based on a previous study (Hellekant and Rudal, 2021) exploring the feasibility of different ECR solutions, the most preferable ones were selected for further analysis: street turns at a dry port and dry port storage combined with extended free time. A third solution—container substitution between different shipping lines—was added to our analysis given its assumed potential to heavily impact ECR reductions. By doing so, we combine different ECR measures in our model, namely street turns, inland transportation infrastructure such as dry ports and collaboration schemes such as extended free-time and container substitution. Our study extends previous research (Erdoğan and Kabadurmuş, 2020) by investigating a real setting to assess the cost-related and environmental impacts of ECR through street turns and enhanced functionality of dry ports through longer free-time for EC storage. Contrasting previous research (Cai et al., 2019) we treat extended free-time not as a cost compensation factor but ECR facilitator.

2.1. Dry ports' role in ECR

A sustainable intermodal transport solution, a *dry port* refers to an inland intermodal terminal directly connected to a seaport by rail where customers can leave and/or retrieve their containers as if directly at the seaport (Roso et al., 2009). That definition implies two important elements of the concept of the dry port: a high-capacity transport connection between the seaport and the dry port and the seaport's inland interface, meaning a facility offering services usually available at seaports and related to handling containers. In that light, one of the concept's most apparent environmental benefits is the use of high-capacity transport modes across long distances. After all, in the shift of container transport from road to rail, if rail is electrified, then the CO2 emissions from transport can be significantly reduced (Roso, 2007). Another benefit is the availability of logistics solutions closer to the final customer in areas usually in need of development. As such, dry ports can be viewed as having stimulated regional development, and, indeed, regions with dry ports have become more attractive for new businesses (Božičević et al., 2021). At the same time, the concept's many potential benefits can differ depending on the actors in the transport system involved, the regions and/or countries where dry ports are implemented, the geography, and the reason for the dry port's implementation (Khaslavskaya and Roso, 2020). Majority of dry ports in Sweden are implemented by municipalities and/or in collaboration with land-based transport operators (Khaslavskaya and Roso, 2022) following the model of Inside-Out directional development according to (Wilmsmeier et al, 2011) resulting in more customer oriented services and more benefits for the land based actors involved. In comparison to the Outside-In directional development, e.i. initiated by the seaside actors, like seaports, that usually generates more benefits for the seaports (Wilmsmeier et al, 2011). Based on the directional development, services at dry ports vary from the basic, including transhipment and the storage of containers, to the more customer-specific, including sorting and kitting (Bask et al, 2014; Khaslavskaya et al., 2021). The primary actor that drives the development of such services is usually the primary beneficiary of the dry port and its services. For instance, if a seaport lacks operational space and thus stimulates the development of a dry port, then that dry port is likely to offer storage for EC, or what are called "dry port depots" (Roso et al., 2009).

Due to the modal shift and services provided, dry ports can facilitate emissions reductions per kilometer and lower costs due to the movement of EC by rail, the availability of storage space close to customers, and, oftentimes, a unique transport operator that can coordinate operation to minimize EC movements. Although some of those opportunities with dry ports have already materialized, their effects have yet to be quantified. Beyond that, operators may also adopt ad hoc improvements instead of having a systematic optimization of flows in place. Thus, the ECR strategies discussed herein are based on the availability of a dry port infrastructure but also combined with different collaboration schemes.

2.2. *Street turns*

A *street turn* (a.k.a. "triangulation") is an operational strategy that shortens the distance traveled. Instead of returning an import container stripped at a consignee/importer to a port terminal, the EC is directly transported to a shipper/exporter, stuffed with export cargo there, and subsequently transported to a port (Fig. 1). Finding an export request for an imported container before it returns to the port is referred to as a match-back which results in the street turn of a container. That strategy eliminates two types of EC movements—from the importer to the terminal and from the terminal to the exporter—while adding only one EC movement, namely between the importer and the exporter (Jula et al., 2006). From a local and regional perspective, street turns reduce the number of empty trips and thereby the distance traveled by trucks (Hanh, 2003). Jula et al. (2006) have studied ECR in the Ports of Los Angeles and Long Beach and concluded that street turns can significantly reduce costs and congestion, hence emissions, noise, and drive times for truck drivers, all depending on the geographical proximity between the importer and the exporter.

However, identifying suitable street turns is quite difficult (Smilowitz, 2007). The literature lists several barriers to street turns, including timing and location mismatch, ownership mismatch, container type mismatch, and legal issues (Jula et al., 2006). Identifying suitable situations with geographical proximity also complicates street turns due to the trade imbalances that exist between regions that are usually import- or export-dominated (Sterzik, 2013). Further barriers include limited free time, repair charges, inconsistent procedures for interchange, inspection and paperwork requirements, and commercial, insurance, and liability hurdles (Braekers et al., 2011).

Studies in the literature have mostly approached street turns from the perspective of shipping lines (Jula et al., 2006; Deidda et al., 2008; Furió et al., 2013). More recently, however, Legros et al. (2016) and Legros et al. (2019) have considered the perspective of the importer. In two case studies in Sweden, other authors have found that transport operators and freight forwarders played a key role in operationalizing street turns (Hellekant and Rudal, 2021; Karlander and Tegbrant, 2021). Other work has described collaboration-oriented initiatives, wherein transport operators exchange EC with each other to increase street turns—in other words, *container substitution* (Sterzik, 2013; Caballini et al., 2016). In our study, we first focused on the ECR strategy of street turns to and from a dry port as a means to use the proximity between the importers and exporters, or what Jula et al. (2006) have termed *depot direct*.

2.3. *Extended free temporary storage at dry ports*

Match-backs of containers can be implemented via a direct street turn, as explained above, but if the time lapse between an import and an export request is too long the container may need storage in the proximity of the importer. In essence, instead of being returned to seaports or depots located near seaports, stripped containers can be stored at locations closer to shippers in anticipation of demand for the container in hinterland transport (Braekers et al., 2011; Kuzmicz and Pesch, 2019). Dry ports can serve as such locations by temporarily storing ECs (Fig. 2) when a direct street turn is not possible (dashed line in the Fig. 2). For example, Bergqvist and Monios (2021) have described how the Falköping terminal in Sweden acts as an EC depot for the region's customers. In such cases, when transport demand arises, an EC can be transported a shorter distance to the importer, stuffed, sent back to the dry port, and transported to the seaport by rail when the intended vessel's estimated time of arrival approaches. That practice is generally more beneficial for

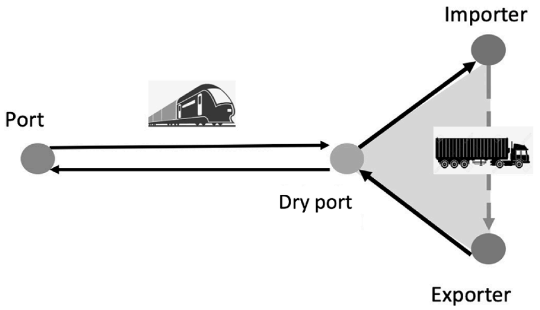

Fig. 1. The street turn.

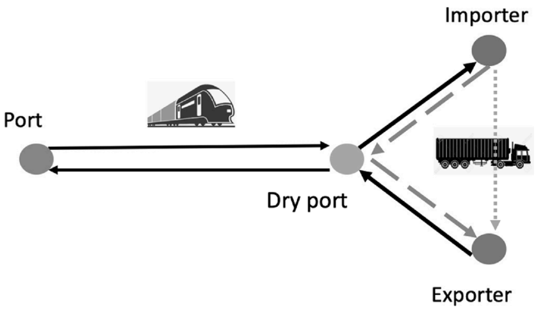

Fig. 2. Extended free temporary storage at a dry port.

shipping lines, however, because the storage fees at dry port depots are usually lower than at seaport terminals and because special contracts can be signed between shipping lines and dry port operators for low fees. Using dry ports for EC storage is beneficial because the shorter distances that they create (Hagelin and Knutsson, 2020; Hellekant and Rudal, 2021) reduce transport costs and thus pollution, fuel consumption, and port congestion (Boile et al., 2008). Recent studies have shown that ECR at dry ports indeed benefit both the seaport and the dry port depending on the prices of repositioning and revenue sharing (Luo and Chang, 2019; Hellekant and Rudal, 2021).

The literature also underscores the importance of the EC storage location. High trade volumes are important for busnisses (Boile et al., 2008), and their imbalance may result in a surplus or deficit of ECs at a certain location (Olivo et al., 2013). Furthermore, container ownership needs to be considered because dry port depots may serve specific shipping lines only (Boile et al., 2008). Other uncertainties relate to cut-off times for container returns to the dry port, delays, the risk of damaged containers, and unexpected demand (Olivo et al., 2013), whereas costs stemming from container storage at dry port depots (Hagelin and Knutsson, 2020) include setup as well as handling and storage. In the short term, because those extra costs tend to be high, shipping lines avoid purchasing such services. Unsurprisingly, to minimize their operational costs, shipping lines are more prone to store ECs closer to the port area and to minimize the total number of storage locations (Boile et al., 2008; Hellekant and Rudal, 2021).

However, storage costs at dry ports, as inland locations, are usually lower than at port terminals (Roso et al., 2009). Furthermore, positioning ECs at such locations can increase the catchment area of transport demand (Bergqvist and Monios, 2021). An important concern in that context is the free time that an importer or exporter has before returning a container to the location that the shipping line pinpoints. Shipping lines offer varying free times depending on the geographic location, container type, and special agreements with the cargo owners and charge demurrage or detention fees if the free time elapses (Kuzmicz and Pesch, 2019). Thus, after unloading, importers seek to send ECs back within the given free time, while exporters seek to send loaded containers on time to avoid the fees. Accordingly, dry port operators tend to send those ECs back to the seaports when they are returned from importers. However, if a dry port operator is given additional free time to store the ECs, then the possibility of finding a matching export demand increases, and redundant EC movements can be avoided. Altogether, the second ECR strategy that we examined involves giving such extended free temporary storage to operators to appropriately match returned ECs with export demand (Kuzmicz and Pesch, 2019). It is northworthy that this strategy includes the direct street turns when demand of EC occurs within two days after stripped at the importer location.

2.4. Collaboration between shipping lines: Scenarios of container ownership substitution

Container substitution is a means of relaxing the constraint of container type while meeting the demand for ECs (Chang et al., 2008) to reduce ECR costs—that is, supplying the demand of one type of container with another type. In that context, *type* refers to three primary features of containers: intended use (e.g., general, refrigerated, or hazmat), size (e.g., 20 ft., 40 ft., or high cube), and ownership—for example, by a shipping line (Chang et al., 2008). All three features can be mismatched. For example, *ownership mismatch* means that importers and exporters located nearby do not use the same shipping lines and thus cannot use the same containers (Sterzik, 2013). In response, ownership container substitution can involve box or container swapping, borrowing, or interchange. For instance, Boile et al. (2006) has described a formal box-matching interchange scheme and ad hoc one-to-one equipment interchanges between shipping lines. However, the literature raises several barriers to container interchange that warrant attention.

Although shipping lines have long exchanged slots on board vessels, exchanging containers is more complicated (Edirisinghe et al., 2016). For example, the intended destination of a container is important to shipping lines, for they need to consider the demand for the container to be loaded with new cargo at or near the destination. Although we studied local ECR, reasons why international shipping lines may be less interested in container sharing, for example, are tied to global container management and imbalances therein, in which shipping lines need to secure sufficient equipment in the right location at the right time at both ends. Edirisinghe et al. (2016) have also reported that there is no mechanism to quantify benefits in advance, which makes shipping lines reluctant to share containers. Moreover, Basarici and Satir (2019) have outlined reasons why container exchange is not preferred by shipping lines, while Kolar et al. (2018) have concluded that the potential of collaborative approaches is influenced by shipping lines' lack of interest in sharing container management strategies. Many alliance agreements have provisions for the interchange of containers (Edirisinghe et al., 2016), although those authors noted that many shipping lines do not wish to try container sharing. Meanwhile, Song and Carter

(2009) have described container-sharing strategies that reduce costs but stressed their impossibility due to competition between shipping lines and the complex coordination of the global network. Imbalances due to container surpluses or deficits in particular ports and specific trade routes may be similar across shipping lines (Song and Carter, 2009), thereby making the sharing of containers of limited interest. Rodrigue and Notteboom (2013) have also described the difficulty of establishing container pools because many shipping lines use containers for branding. Nevertheless, even if the literature stresses that interest among shipping lines in collaborative approaches for sharing containers is low, the benefits from a local perspective do not necessarily contradict potential benefits on a global scale.

On that count, Edirisinghe et al. (2016) have identified five factors influencing container interchange between shipping lines: operational factors, legal factors, branding, benefits, and feasibility. The collaboration decision and the level of collaboration is highly dependent on these five factors. Operational factors such as economies of scale and cost efficiencies, for example, act as facilitators of collaboration. However, the scale of operations such as service scope, service frequency or slot allocations affect the feasibility of any collaboration attempt. Legal factors in combination with branding and marketing strategies hinder collaboration for container exchange as containers act as brand communicators for ocean carriers. Although the benefits of collaboration are emphasized and demonstrated by many studies, operational and strategic barriers maintain their stronger weight in the decision equilibrium.

To be sure, container ownership mismatch is a primary barrier to reducing ECR by, for instance, limiting street turns (Braekers et al., 2011; Karlander and Tegbrant, 2021). In our research, we approached that mismatch by modeling the collaboration scheme with three possible scenarios: full collaboration, alliance collaboration, and no collaboration. Hence, we decided to investigate the collaboration scheme with a gradual approach and introduce three levels in the model.

First, *full collaboration* means that shipping lines collaborate in such a way that container substitution is always possible for shippers. Practical examples of such collaboration have been reported in the context of grey unbranded containers (Theofanis *et al.*, 2009).

Second, regarding *alliance collaboration*, since the early 1990s the liner shipping industry has been characterized by strategic alliances between otherwise intensely competing rivals in pursuit of diverse objectives, including investment sharing, joint operational planning, economies of scale, entry to new markets, and wider ranges of service offerings (Chen et al., 2022; Song and Panayides, 2002). A potential objective of those alliances can be container substitution, which we included in our scenarios. Tong and Yan (2018) have termed the alliance *EC alliance* and provided evidence of the benefits of such collaboration not only within but also across such alliances.

Third and last, the scenario of *no collaboration* represents a situation in which shipping lines run their own ECR operations, are reluctant to share containers, and/or put the pressure on other network actors to make ECR efficient. For instance, Theofanis *et al.* (2009) have described how freight forwarders try to convince their customers to switch shipping lines in order to provide a better match, as well as how export companies are interested in finding companies with matching import flows.

In sum, we assessed two ECR strategies with respect to their potential efficiency-related benefits—street turns and extended free temporary storage at dry ports —in three scenarios with different degrees of collaboration in container substitution: no collaboration, alliance collaboration, and full collaboration.

3. Method

In our case study, we examined an intermodal network for inland transport of containers via dry port in Sweden. Swedish dry ports have been studied from various perspectives such as environmental perspectives (Roso, 2007), the potential of dry ports to mitigate supply chain disturbances (Gonzalez-Aregall and Bergqvist, 2019), or directional development impacts (Bask et al., 2014). However, research on dry port's role in movement of ECs in Sweden is scarce despite the demand; and shows that there is a need to further explore and understand the role of dry ports in the country's intermodal transport chain of ECR. Furthermore, Port of Gothenburg with wide network of intermodal terminals in its hinterland, 11 of which are dry ports with direct rail shuttles to the port (Khaslavskaya and Roso, 2022), is rather unique setting to study the hinterland's ECR. Fig. 3 shows the geographical scope of the case study, which encompassed an intermodal connection of rail (i.e., Gothenburg–Eskilstuna) and truck (i.e., Eskilstuna–customers) between Port of Gothenburg - Scandinavia's largest container port—and customers, meaning import and export companies served by Eskilstuna dry port. Data for the study were collected from the databases of container movements on the chosen route concerning the case in 2019–2021 and from interviews with the transport operators involved in the studied transport chain.

The case study afforded a convenient research design by allowing an in-depth exploration of the available data and the continuous validation of results with the case companies involved. For a research strategy, we implemented a quantitative method using multi-paradigm simulation modeling. Simulation modeling was selected based on the versatile set of functions offered (e.g., demand stochastic behavior, dynamics over time, representation of transportation networks, and companies' interactions under collaboration strategies) to deal with system-level complexities.

The aim of our analysis was to assess specific strategies of collaboration in terms of ECR metrics (e.g., distance, emissions, and cost). Examining decisions about network configuration, fleet sizing, and vehicle routing that would imply additional methods from operations research (e.g., optimization) was beyond the scope of our study. As a result, this paper is one of a series of studies, both quantitative and qualitative, aimed at elucidating the dynamics of ECR and improving the energy efficiency of such operations (Hellekant and Rudal, 2021; Karlander and Tegbrant, 2021; Xu and Ibrahim, 2022).

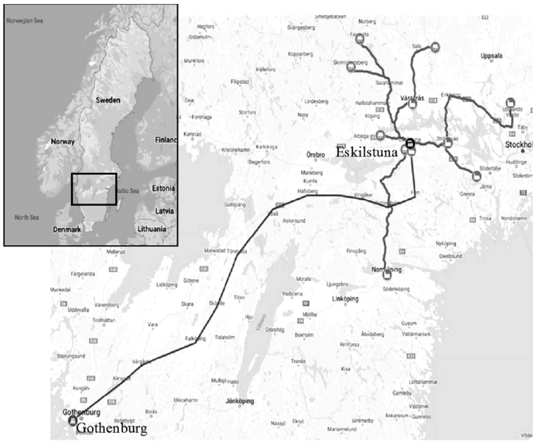

Fig. 3. Geographic scope of the case study.

3.1. Case study: Eskilstuna dry port

Eskilstuna Intermodal Terminal,[3] located in the Stockholm–Mälardal area in the municipality of Eskilstuna, was initiated by Eskilstuna municipality after negotiations with H&M to build their distribution center in the area in 2002 and finally established in 2003. Owned by the Municipality of Eskilstuna via Eskilstuna Logistik och Etablering AB, the dry port was operated and managed by rail operator Green Cargo but since 2004 has been operated by M4, which rents the terminal from the municipality but owns the machinery and retains its own employees. The terminal, with four loading and unloading tracks 750 m each and capacity of handling 300,000 units annually, has a rail connection to the Ports of Gothenburg, Malmö, and Trelleborg provided by Green Cargo, GDL, and TX Logistik (Khaslavskaya and Roso, 2022). Although the biggest shippers using the services of the terminal are H&M, BSH Home Appliances, Amazon, ICA, Volvo, and Coop, many small-scale customers use it as well. Added to standard services such as container handling, storage, and a depot, the terminal is capable of arranging other types of services, including reefer plugs, customs clearance, and the maintenance of loading units on demand from customers (Khaslavskaya et al., 2021).

The rail connection between Eskilstuna dry port and the Port of Gothenburg (i.e., APM terminal) delimited the scope of our case study. The freight train leaves the APM terminal at 23:00 every workday and arrives at Eskilustuna dry port at 05:00 the next day. Unloading and loading activities begin immediately upon the train's arrival, and, once they are completed, the train departs at 10:30 and arrives at the seaport at 18:30 later that day. That operational routine corresponds with the rail company that participated in the case study. In all, the train can carry up to 44 containers or 600 tons of cargo. The whole transport system works five days a week, from Monday to Friday.

3.2. Multi-paradigm simulation model

In our study, we followed the simulation process approach shown in Fig. 4. The case study provided the input data for defining the problem and analyzing the system's logic. Combining simulation paradigms proved to be a novel approach to representing the system considering variability in container demand, transport routes, and information flows among actors. The literature review contributed to our theoretical framework, and the study of past contributions enlightened our validation process and discussion.

A multi-paradigm simulation model combining agent-based and discrete-event modelling was built using AnyLogic® 8 Personal Learning Edition 8.7.12, recommended by Abdelshafie et al. (2022) as a robust tool for assessing ECR scenarios and policies considering multiple agents and their autonomous decisions and logically linking them together in a single environment. Multi-paradigm modelling, i.e., the combination of two or more modelling paradigms such as system dynamics, discrete-event, agent-based or dynamics systems, enables the representation of interactions among system components at different granularity levels which is rather challenging if only one simulation paradigm is implemented (Lynch et al., 2014). For instance, entities in discrete-event modelling have low levels of autonomy for making or modifying decisions given system conditions, e.g., doing a match-back if a container demand for export randomly occurs and distance and time constraints are met. But, this paradigm is convenient for modelling operational routines such as queueing management, (un)loading, storage, and modelling vehicle dispatching rules (Allen, 2011). On the other side, agent-based modelling adds value to the simulation field by giving entities the possibility of changing behaviours accordingly to system conditions. However, agent-based has low accuracy levels for modelling particular operations such as those handled by the event-discrete paradigm. Therefore, a combination of these two paradigms makes it feasible to represent the ECR system by combining the agent's autonomy to decide on match-back operations with the simulation of the particular process that these decisions imply. Table 1 shows attributes, abstraction level, management level from agent-based and discrete-event paradigms and

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[3] https://www.eskilstunalogistik.se/kombiterminal/.

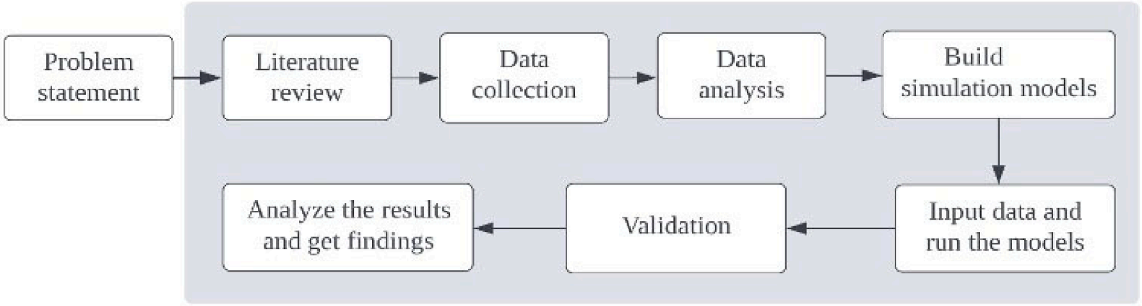


Fig. 4. Simulation process approach.

how they contribute to ECR system representation.

Fig. 5 expands information from Table 1 by presenting the agent-based flow chart and the discrete events, symbolized by ⚡, for the base case of seaport–dry port connection, in the supply of container transport services to customers (i.e., importers and exporters) without any ECR strategy or collaboration involved. The train's itinerary specified in the flow chart represents time-dependent operations of rail services on weekdays.

Fig. 5 distinguishes import from export flows. Import flows imply laden container transport from the seaport to the import company via the dry port terminal. Therein, rail services connect the port and dry port terminals, while truck transport connects the dry port to the customer's location. Once the container is stripped, it is returned to the port through the same transport network. By contrast, in export flows, customers send requests for ECs to the shipping lines, which dispatch them from the port to the customers' location through the dry port terminal. At the customers' location, the container is stuffed and subsequently returned to the port via the same transport network.

The model assumes operational conditions without disruptions or container shortages—in short, that shipping lines will always supply ECs when requested by customers. Assessments of disruptions management using the same case study addressed in Wide et al. (2022) has implications for the likelihood of the simulated results compared with real-world operations. Nonetheless, because our aim was to compare how scenarios with varying levels of collaboration affect emissions, costs, and kilometers traveled, disruptions can be assumed to be environmental conditions indistinct within the simulated experiments (i.e., noise in the experimental design).

The logic of our simulation modeling is complemented with the definitions of attributes, performance variables, decisions, and events for each of the system agents. Table 2 describes the modeling elements considered for each of the agents in the case study. The attributes referred to containers (i.e., ownership, size, and weight), whereas performance variables were the source of the output analyses using the statistical procedures explained by Nakayama (2006) regarding the number of replicates, response variable confidence intervals, and difference significance tests between the experimental configurations.

In Table 2, "Decisions" refers to agents' logic to perform actions and interact with other agents within the system. Those decisions are activated by the occurrence of discrete events linked to the specific decision according to the logic shown in Fig. 5. For instance, the event of "truck loading" at the dry port agent activates a "truck operation decision" from the truck agent, which corresponds to the transport service from the dry port to the customer's location. Those events are modeled using the traditional approach of queuing systems and discrete-event modeling described by Van Tendeloo and Vangheluwe (2018).

Variations on decisions logic were designed to represent ECR strategies. For instance, street turns implied changing the truck's decision of going from an importer's location to the dry port after container stripping, namely by sending it directly to the closest exporter with an active request for an EC if the constraint of container ownership was satisfied. The simulation model encompassed eight experimental configurations, each one representing a different combination of ECR strategies with incremental features: (i) inland network without dry port, (ii) inland network with dry port (i.e., base case), (iii–v) base case and street turns via dry port with the three ownership container substitution scenarios (i.e., no collaboration, alliance collaboration, and full collaboration), and (vi–viii) the base case with direct street turns and additional match-backs enabled by FTDP with the three ownership container substitution scenarios.

Running the simulation model involved running 25 replications of each experimental configuration. The number of runs was determined based on output analysis methods described in (Nakayama, 2006) to achieve response variables intervals at a 95 % level of confidence and an error less than or equal to 1 %. The simulation period was a year, with an additional warm-up period of 3 months to reach the steady state.

As described in Section 2.3, the FTDP strategy entails the temporary storage of EC at the dry port while waiting for a new EC request from an exporter. If the storage time exceeds the limit defined by the shipping line, then the EC is returned to the seaport. Because storage time limits (i.e., usually in days) differ according to shipping line contract conditions, our simulation involved running a sensibility analysis that varied the storage time at the dry port when the experimental configuration included the FTDP strategy. To the list of collected variables from Table 2, for FTDP experiments the model added storage costs that, together with emissions calculations, kilometers traveled, and transport and handling costs, determined the most suitable time limit for the storage of EC at the dry port.

Degrees of collaboration regarding the ownership container substitution strategy were modeled by relaxing the constraint of brand container interchangeability in the cases of alliance and full collaboration. Alliance collaboration encompassed such alliances in

Table 1
Modelling paradigms' scope and role in ECR system simulation.

	Attributes	Abstraction level	Management level	Contribution to ECR system representation
Agent-based modelling	Autonomous agents, individual behaviour rules.	Individual bahaviour influenced by dynamic system conditions	Strategic and tactical decisions	Agents autonomy to decide if a match-back operation is performed – (agent: trucks).
Discrete-event modelling	Entities – passive objects. System operational rules using flow charts – e.g., delays, usage of resources, waiting in queues.	Global system pre-established rules	Tactical and operational decisions	Vehicle dispatching rules – (agent: dry port), (un)loading – (agent: dry port), containers demand generation – (agent: import/export)

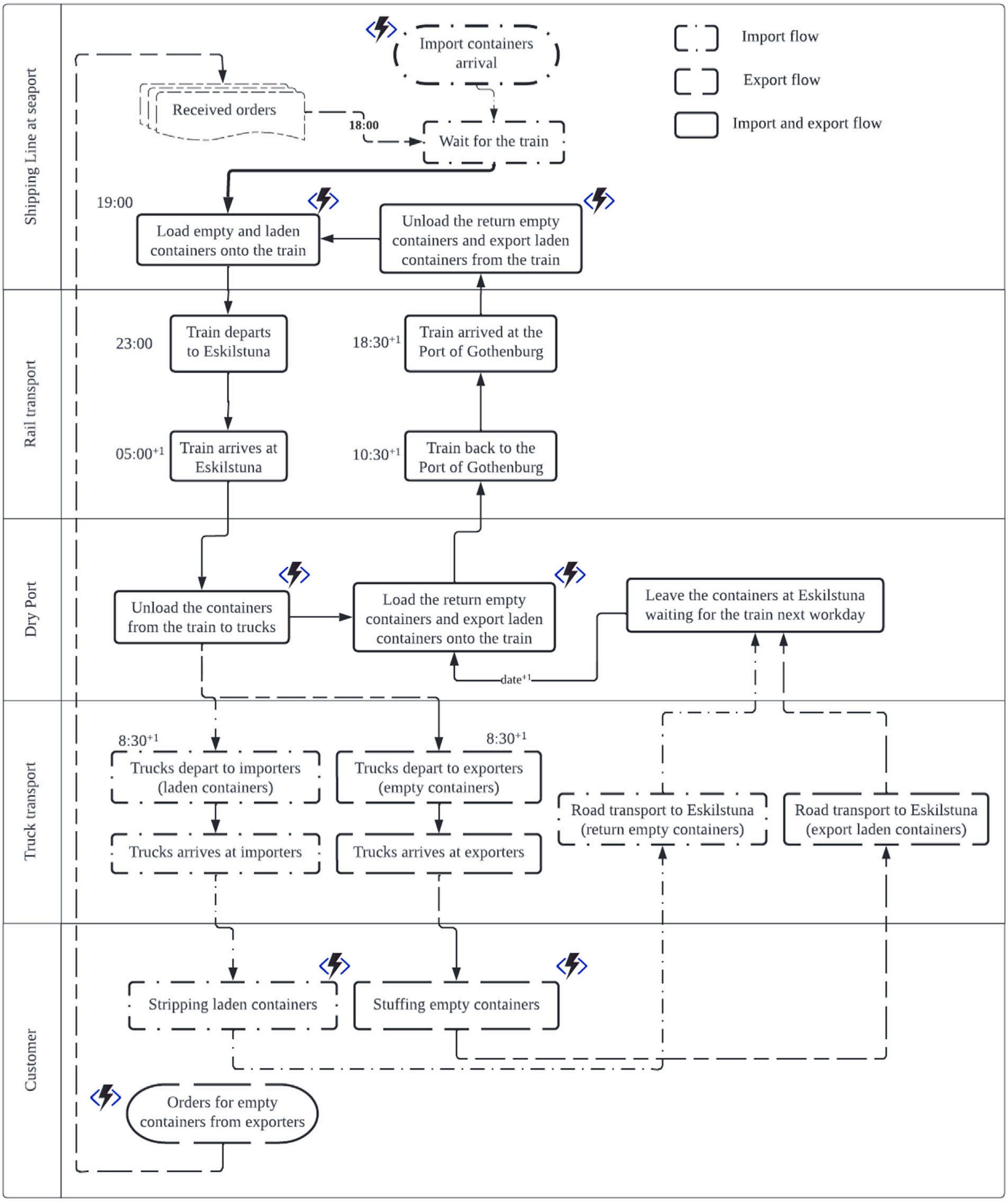


Fig. 5. Agent-based and discrete-event modelling of the ECR case study.

Sweden, including the 2M Alliance (i.e., Maersk and MSC), the Ocean Alliance (i.e., COSCO, OOCL, CMA CGM, and Evergreen), and THE Alliance (i.e., Hapag-Lloyd, ONE, and Yang Ming). A fourth group of shipping lines was formed with all 12 remaining companies not in any alliance, which accounted for 13 % of the operations in the case study. In the full collaboration scenario, the ownership constraint on the EC supply was removed.

Table 2
Modelling elements per agent.

Modelling element	Shipping line or seaport	Dry port	Train	Truck	Customer
Attributes			– Fare – Speed – Emissions rate	– Fare – Speed – Emissions rate	– Location – Imp or exp type
Performance variables	– Number of imp or exp containers – Handling cost	– Number of imp or exp containers – Handling cost	– Number of imp or exp containers – Km traveled* – Cost* – CO_2 emissions*	– Km traveled* – Cost* – CO_2 emissions*	
Decisions	– Releasing ECs and laden containers – Schedule train service	– Releasing ECs (inland depot) – Schedule train or truck service	- Train operation	- Truck operation	
Discrete events ⚡	– Container arrivals – Train loading and unloading	– Train loading and unloading – Truck loading and unloading			– Placing EC orders – Container stuffing/ stripping

Note. imp = import; exp = export; EC = empty container.

* Decision variable.

4. Results

Input data analysis consisted of the descriptive analytics of container movements and fitting procedures for estimating the probability distributions of random variables such as EC demand, import flows, and container handling time. The R Studio libraries *fitdistrplus()* and *gofstat()* processed raw data from export and import demand to identify probability distributions that best fit their behaviour using goodness-of-fit statistics, e.g., Kolmogorov-Smirnov. Inland transport operators and the dry port company provided input data from 3 years of operation (i.e., 2019–2021), for a database containing>176,000 records of a container flows time series (i.e., laden and empty) with features related to type of customer (i.e., importer and exporter) and type of container (i.e., ownership, size, and use). Case companies also provided their customers' locations grouped by municipality, fares for rail and truck services, transportation capacity, rail frequencies, and the dry port's handling and storage costs. Table 3 summarizes the simulation parameters after descriptive analytics and fitting procedures.

Results from descriptive analytics suggested that 10 customers represented 92.44 % of the total flow of containers. A particular feature revealed by the case study, moreover, was that customers, grouped by municipality, performed either import or export operations, with only the Eskilstuna node representing both types. EC demand was fitted to a probability distribution for each of the most

Table 3
Model parameters.

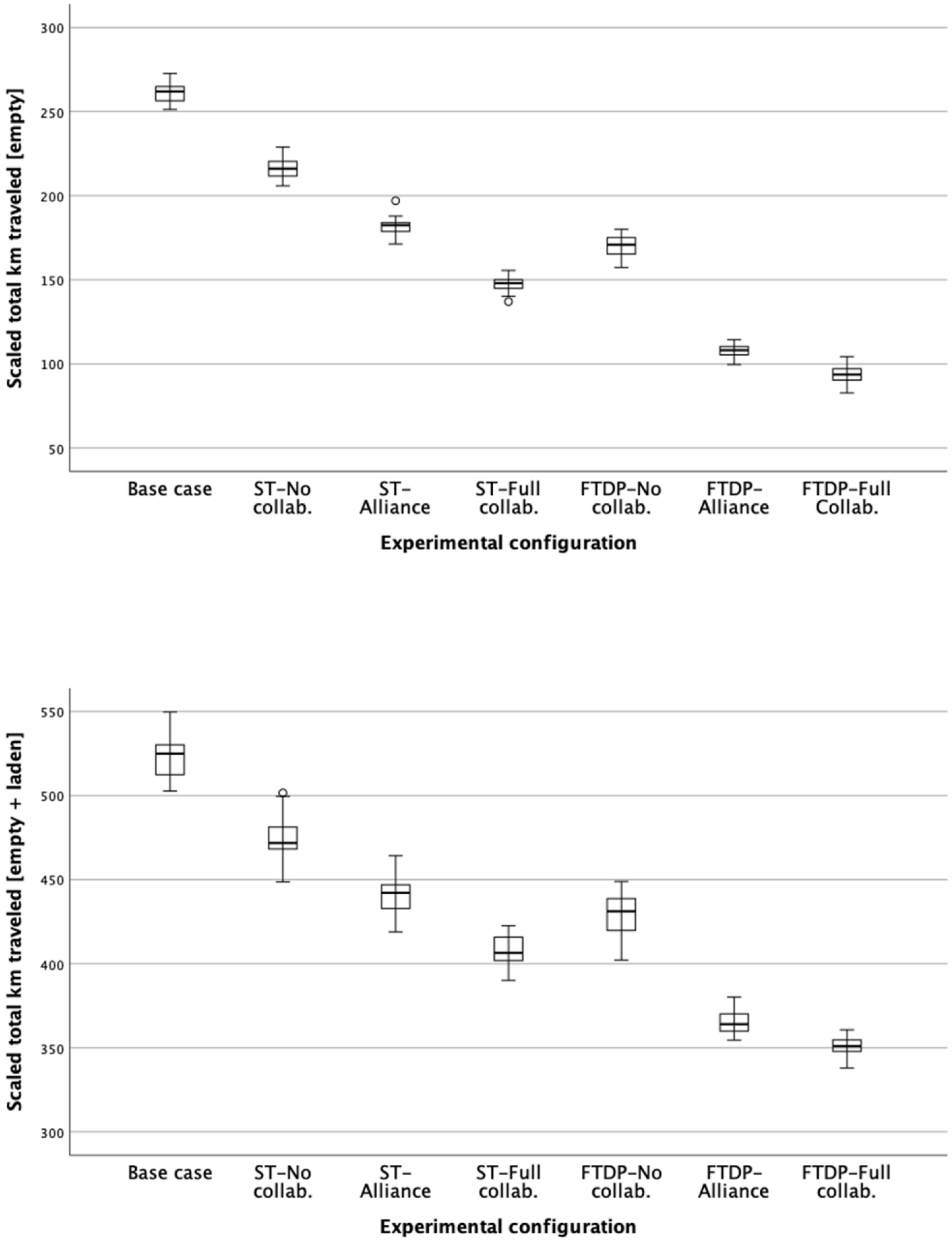
Input parameter	W5	Probability distribution/value
Import containers	Units/day	Normal (15.43, 7.8)
EC demand from exporters at Heby	Units/day	Gamma (1.28, 5.56) if $U > 0.37$
EC demand from exporters at Eskilstuna	Units/day	Lognorm (1.64, 0.84) if $U > 0.31$
EC demand from exporters at Skinnskatteberg	Units/day	Gamma (1.47, 3.70) if $U > 0.31$
EC demand from exporters at Fagersta	Units/day	Gamma (1.90, 2.00) if $U > 0.38$
EC demand from exporters at Kungsor	Units/day	Normal (0.99, 2.05) if $U > 0.13$
Maximum load weight of export containers	kg	25,000
Train transport cost	kr/container-trip	5,800
Truck transport cost	kr/container-km	30.43
CO_2 emission rate for train transport: Full container	g/km	331.10*
CO_2 emission rate for train transport: Empty container	g/km	31.82*
CO_2 emission rate for truck transport: Full container	g/km	915.00*
CO_2 emission rate for truck transport: Empty container	g/km	593.90*
Handling time of containers train ⇔ truck	Days	Triangular (0.1, 0.2, and 0.15)
Containers stuffing/stripping time	Days	Container weight/10,000
Container handling cost at dry port	kr/container	215
Container storage cost at dry port**	kr/container-week	Unif (100, 200) if time > 1 week 0, otherwise

Note. kr = Swedish krona.

* Source: Network for Transport Measures (https://www.transportmeasures.org/en/).

** Only applies when implementing FTDP.

relevant export nodes (i.e., Heby, Eskilstuna, Skinnskatteberg, Fagersta, and Kungsor). Randomness in the occurrence of an EC requirement was considered through a random variable, U, which activated the event called “placing an EC order” from the “customer” if its value exceeded the threshold shown in Table 3. Import containers per day fitted a normal distribution ($M = 15.43$, $SD = 7.8$), and their allocation to the most relevant customers was based on historical rates per customer: 45.14 % for Eskilstuna, 30.8 % for Nykvarn, 6.93 % for Arlandastad, 2.65 % for Strängnäs, and 1.84 % for Norrköping.

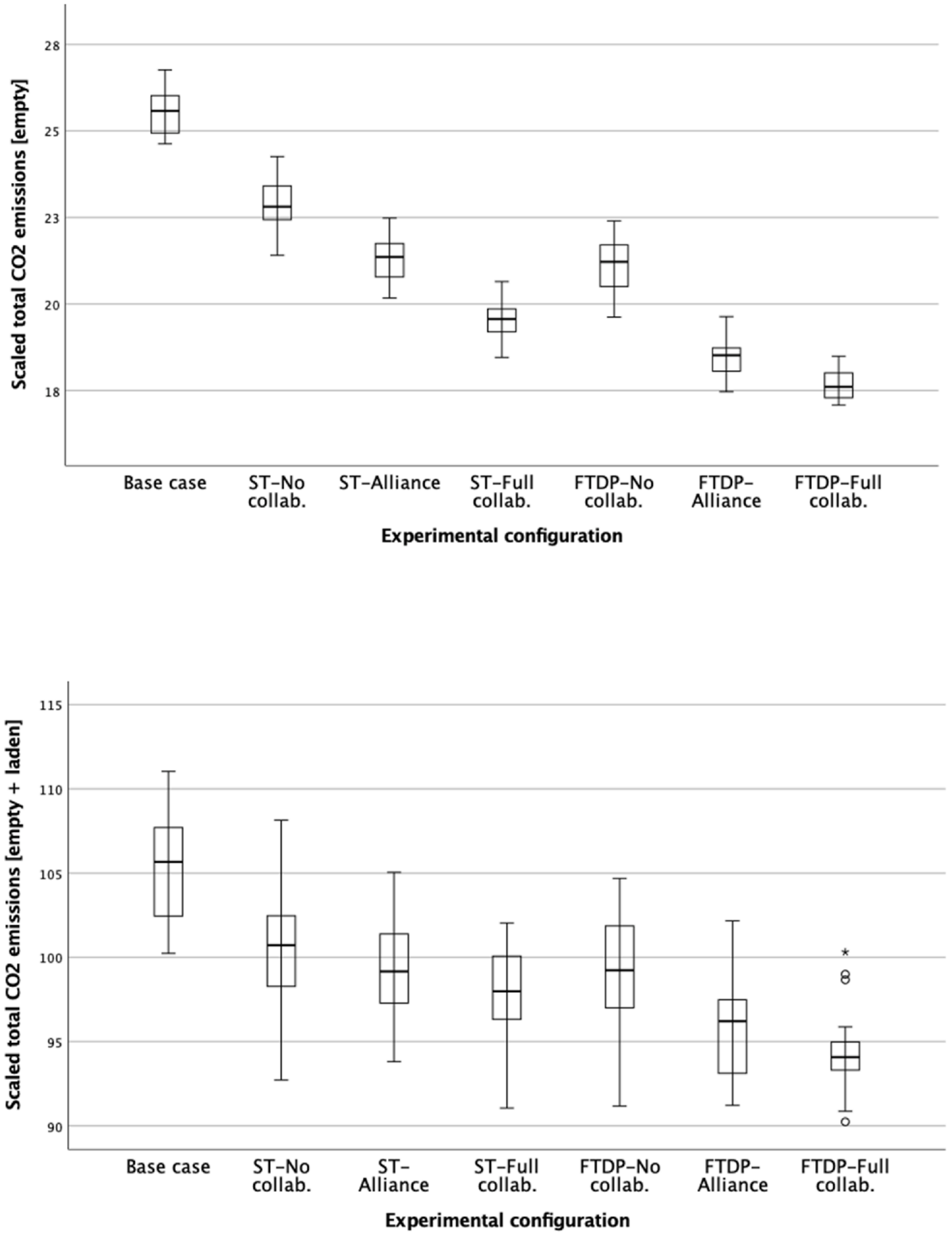


Note. ST = street turn.

Fig. 6. ECR km traveled (top) and system km traveled (bottom).

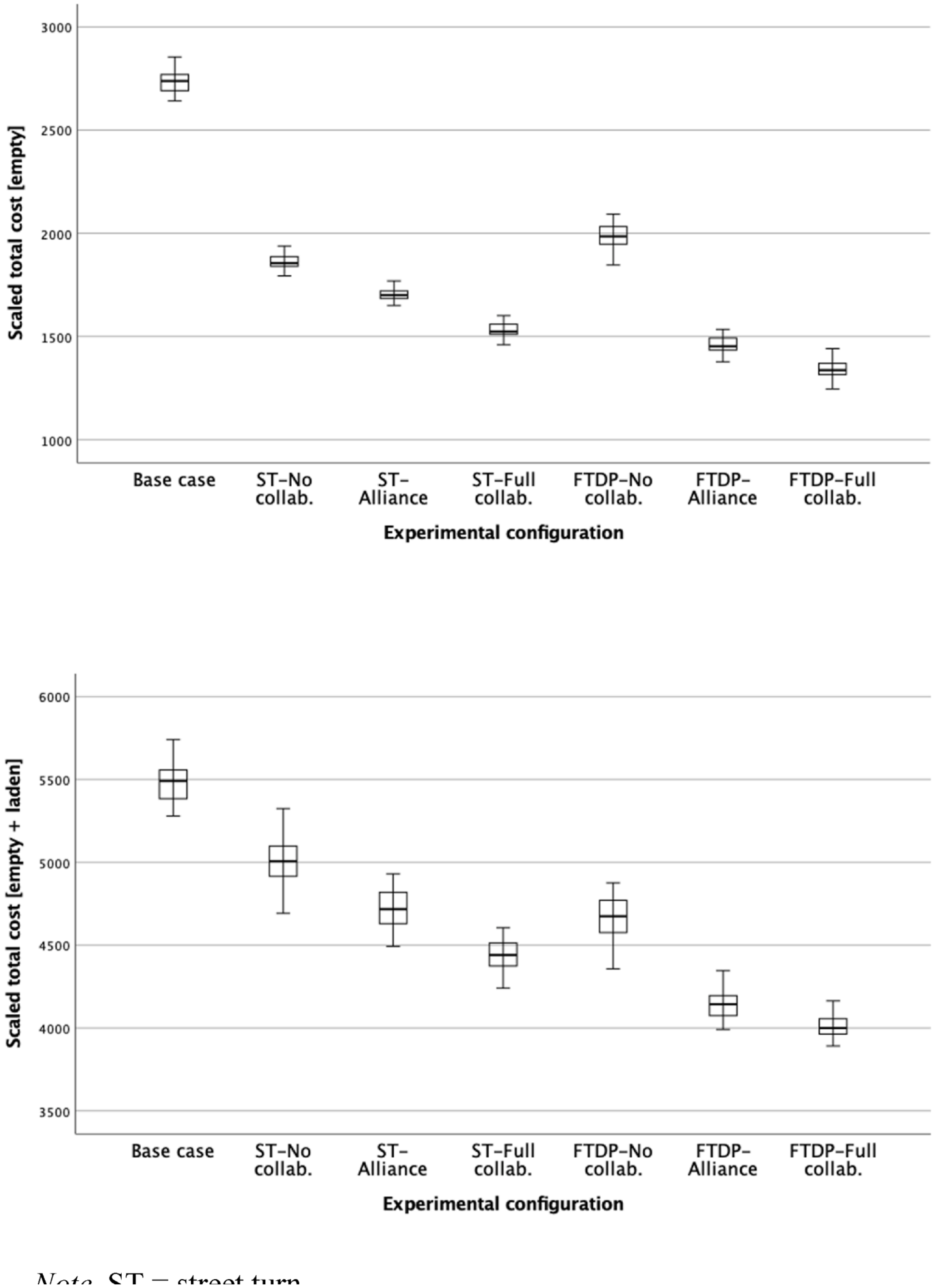
Historical data served as a reference for validating the results of the simulation. In the validation process, when comparing the current scenario results to historical data in terms of the number of containers that flowed through the system, the *t* test failed to reject the null hypothesis of equal means ($p = .023$), thereby suggesting that the simulation model validly represented the real-world system's dynamics.

Figs. 6–8 present the results for ECR and the system-level (i.e., ECs and laden containers) decision variables (i.e., kilometers traveled, CO_2 emissions, and costs) for seven experimental configurations: a base case, three levels of collaboration with street turns, and three levels of collaboration with FTDP. The graphs show, as expected, a high correlation between the decision variables, thereby clarifying that looking for environmental benefits in ECR management necessarily leads to cost-efficient performance, and vice versa.



Note. ST = street turn.

Fig. 7. ECR CO_2 emissions (top) and system-wide CO_2 emissions (bottom).



Note. ST = street turn

Fig. 8. ECR costs (top) and system-wide costs (bottom).

Hereafter, improvement in both aspects is referred to as *eco-efficiency*.

Although the case study operated under the condition of having a dry port, one experimental configuration assumed its non-existence (not shown in the figures). The results revealed the relevance of the dry port in leveraging ECR's eco-efficiency. Operations driven by dry ports improved the system's performance metrics from 63 % to 70 %, owing to long-distance electrified rail transport (i.e., ~400 km) and its economies of scale (i.e., 44 containers per trip). Impacts may vary in other contexts, however, due to conditions where train capacity differs, non-electric trains operate, and/or dry ports are closer to the seaport (e.g., Roso, 2007). Trade imbalances also feature the extent of the impacts of ECR operations through the dry port. For instance, imports were around three times bigger than exports in terms of container movements in the region of study. Therefore, reducing ECR via match-backs using the dry port, had an upper limit at one-third of containers in the system.

According to the simulation results, the effects of direct street turns are beneficial in reducing ECR costs, although environmental benefits are amplified under collaboration-intensive scenarios of ownership container substitution. For instance, with the base case as a reference, the total reduction in the cost of street turns ranged from 7 % to 10 % for the whole system, without any collaboration between container owners by matching 26.83 % of the export containers to prior import container operations. The reduction in CO_2 emissions did not exceed 6 %. Those reductions were nearly twice as high as in the scenario involving the full collaboration of container owners given that matching import to export container demand were possible for 67.55 % of the export containers. Cost savings shown in Fig. 8 suggest a steep reduction—in fact, up to 44 % under full collaboration—but only when ECR was assessed. That reduction was smaller, as was the drop in emissions savings, when considering empty and laden container operations. Nonetheless, the magnitude of savings for the system remained significant ($p < .001$) with respect to the current scenario. Such savings could motivate shipping lines and actors in the logistics chain to invest in technology and human resources required for implementing street turns, particularly ones who have seemed reluctant to do so, as previously reported (Theofanis and Boile, 2009).

Adding the possibility of a FTDP amplified the benefits of street turns. Its impacts on eco-efficiency were nearly twice as high due to the increased probability of finding a match-back when extended EC storage was possible at the dry port. Storage time increases the possibility of match-backs since ECs that are not directly street turned can stay at the dry port until an export match is achieved. Nonetheless, it may imply negotiations between freight forwarders, dry port operators, and shipping lines, regarding EC drop-off time, location, and, storage and demorage costs. The sensibility analysis in Fig. 9 showed that having ten days of storage at the dry port made match-backs possible for 100 % of the export containers when full collaboration was implemented. Under the scenario of no collaboration, match-backs occurred for 54 % of the export containers. Since ten days of storage limit maintained a positive balance between ECR savings and storage costs, FTDP impacts were computed using ten days as a storage time parameter.

The implementation of FTDP generated savings in the system's cost compared with the base case, namely between 13 % and 17 % in the absence of collaboration between container owners. For ECR, costs fell by up to 29 %. Reductions in emissions, system-wise, fluctuated between 4 % and 7 % without collaboration but were 1.5 times greater when container owners collaborated. Considering ECR alone, reductions in environmental impacts reached up to 32 % under full collaboration with ownership container substitution. In the absence of collaboration, the reduction in CO_2 emissions did not pass 19 %.

5. Discussion

This paper aimed at assessing the environmental and economic benefits of ECR operations at dry ports. Using a multi-paradigm modelling, we simulated an ECR system having the link Port of Gothenburg– Eskilstuna Dry Port (Sweden) as a case study. Experimental results showed the impacts of dry-port-based strategies, i.e., street turns and FTDP, on kilometers traveled, cost and CO2 emissions, of an ECR system under three different scenarios of collaboration between shipping lines.

According to the simulation outputs, with both street turns and FTDP, ownership container substitution duplicated benefits in eco-efficiency performance. An analysis of variance (ANOVA) also showed that the effect of both strategies, the three collaboration scenarios, and their interaction were statistically significant (p-value: 0.042, 8.03×10^{-69}, 4.81×10^{-47} respectively) in reducing cost, emissions and kilometres travelled. Meaning that the mechanisms of collaboration have tremendous potential to generate benefits for the liner shipping sector, although some challenges remain. According to Hagelin and Knutsson (2020), shipping lines struggle to determine who owns the right to the shared containers and where to ship them, which creates problems about who is most entitled to a container in light of a shortage, for example. Nonetheless, results from our simulation show that current alliances generate nearly as many benefits as full collaboration, at least in the environmental aspect ($p = .096$), and thus represent a first step toward an ideal scenario of full collaboration.

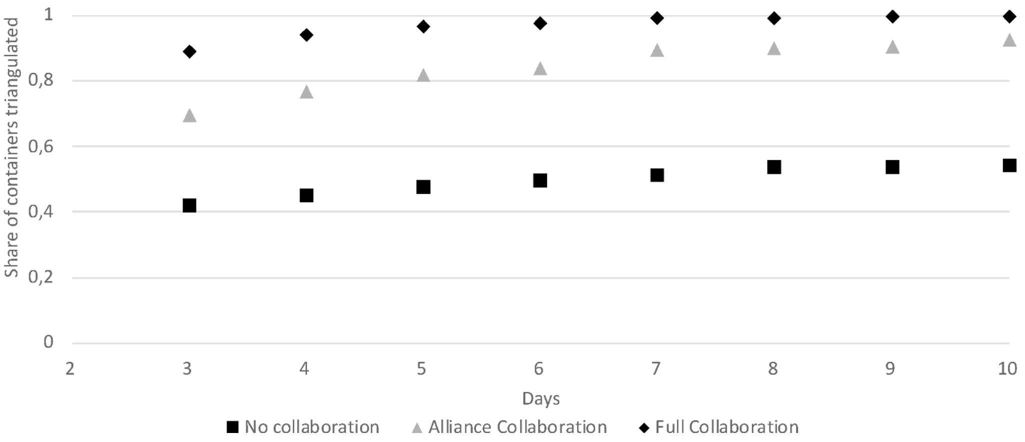


Fig. 9. Sensibility analysis of free days for dropping off empty containers.

To realize the suggested improvements, which barriers exist needs to be understood as well as how they can be overcome. The literature provides several challenges for implementing the ECR strategies of street turns and FTDP under specific collaboration-related scenarios (i.e., no collaboration, alliance collaboration, and full collaboration, please see section 2.4 for a detailed discussion). Furthermore, the literature on container sharing primarily takes the perspective of shipping lines, whereas a multi-actor approach would reflect the perspectives of other involved parties (e.g., shippers, transport operators, and forwarders). Kolar et al. (2018) have described that literature on inland repositioning focusing on interorganizational collaboration is less extensive than the stream focusing on maritime repositioning and intraorganizational collaboration. To overcome those barriers and realize the improvements suggested herein, multiple actors need to change their behavior. For example, for the extension of free temporary storage at a dry port, results shown in Fig. 9 evidenced the difference between 3 and 10 days, whereas shipping lines have expressed concern that longer FTDP could reduce importers' incentives to return empty containers as quickly as possible. Consequently, that dynamic might lead to increased turnaround times for containers and shipping lines' needing more containers overall. Furthermore, depending on a dry port's ownership, FTDP's benefits might be interpreted differently for the dry port operator—that is, either as a loss of profit due to free storage days for the greater cause of lower environmental impacts resulting from reduced ECR, or increased profit due to increased container volumes from new customers (Bergqvist and Monios, 2021) resulting from generous policies of offering free storage days. Further research is therefore needed on the interaction and implications for several actors that might have conflicting interests.

In our work, we have extended previous research (Erdoğan and Kabadurmuş, 2020) by combining street turns with new conditions such as extended free-time and studying this with real case data. Having a different approach from previous research that treats detention time as a revenue source (Cai et al., 2019) we treat it as a condition to facilitate more efficient ECR processes that enable cost and emission reductions. Notably, in the scenario without collaboration, FTDP generated as much savings as in scenarios with street turns. Therefore, efforts in detention fees and negotiations about storage days at the dry port are unlikely to generate extra eco-efficiency benefits as expected when collaboration exists. However, combining the strategies could provide even further improvements and savings. It should also be noted that our case study took place in an import-dominated region, meaning that there are usually containers that have been stripped of cargo available for new export cargo, which increases the general interest in storing containers at inland destinations such as dry ports. Such problematic unbalanced flows due to trade imbalances have even been observed globally in several geographical areas. Gusah et al., (2019) have described Melbourne, Australia, as an import-dominated port that generates an abundance of empty containers that cannot be used for export due to different weight capacity restrictions on types of imported and exported cargo. Those authors concluded that in a multi-actor system in which objectives often conflict, a holistic approach is required to create system-level efficiency and reduce externalities. Furthermore, the transport network infrastructure in Sweden, with extensive road and rail connections to several dry ports (Khaslavskaya et al., 2021), makes our results interesting to other regions of Sweden.

The method applied to this case can be applied to different contexts to assess the effects of different strategies on eco-efficiency. As shown in this study, there are some key factors that should be considered case by case as they have a major effect on the eco-efficiency metrics, i.e., the magnitude of the trade imbalance in the assessed region, transport energy sources, distance travelled and transport modes connecting the port and dry ports, train connection between the studied nodes, proximity between exporters and importers, and shipping lines services offered in the region. Further research will study the effects of connecting different inland terminals for triangulation and idenfity more factors that can influence the benefits of street-turns and FTDP on eco-efficiency.

6. Conclusion

In our work, we developed a method of quantifying environmental and economic benefits of ECR strategies at dry ports in Sweden. A simulation study revealed the high impacts of the dry ports on inland transportation's eco-efficiency, namely with cost and emissions reductions of up to 70 %. We also assessed the impacts of different experimental configurations of ECR strategies via dry ports (i.e., street turns and FTDP) considering scenarios involving collaboration between shipping lines with different levels of container substitution. These configurations aimed at reducing ECR movements by achiving match-backs between import and export containers in an inland transport network, although limited by trade imbalances. When implementing the two strategies, the mechanisms of collaboration amplified the benefits of eco-efficiency to factors of 1.6 and 1.8 with alliance collaboration and full collaboration, respectively. The FTDP strategy with full collaboration among container owners outperformed the base case and five other combinations of ECR strategies. Its benefits in emissions reduction for ECR reached 32 % and even exceeded 50 % in costs with respect to the baseline scenario, although managerial strategies and collaboration schemes need to be in place to overcome challenges related to container administration and disruption management.

Our research has contributed to assessments of ECR from an inland, intermodal, and multi-actor perspective via dry ports, which complements recent literature focused on road transportation provided by a single focal company or actor. We have also added environmental aspects to the analysis of inland ECR, which has traditionally been dominated by cost and operational evaluations. The use of big data from a real case also bolsters the practical implications of our research.

Future research could explore the development of combined global and regional ECR models and the design of collaboration strategies in that wider geographical scope. More research is also needed regarding strategies to overcome the effects of trade imbalance in ECR by assessing, for instance, dry ports collaboration. Also, future research could explore methods for including the occurrence of disruptions (e.g., container shortages) and transport network contingencies in the evaluation of ECR strategies. Tools for improving the transferability of findings are also needed that consider context-dependent conditions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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