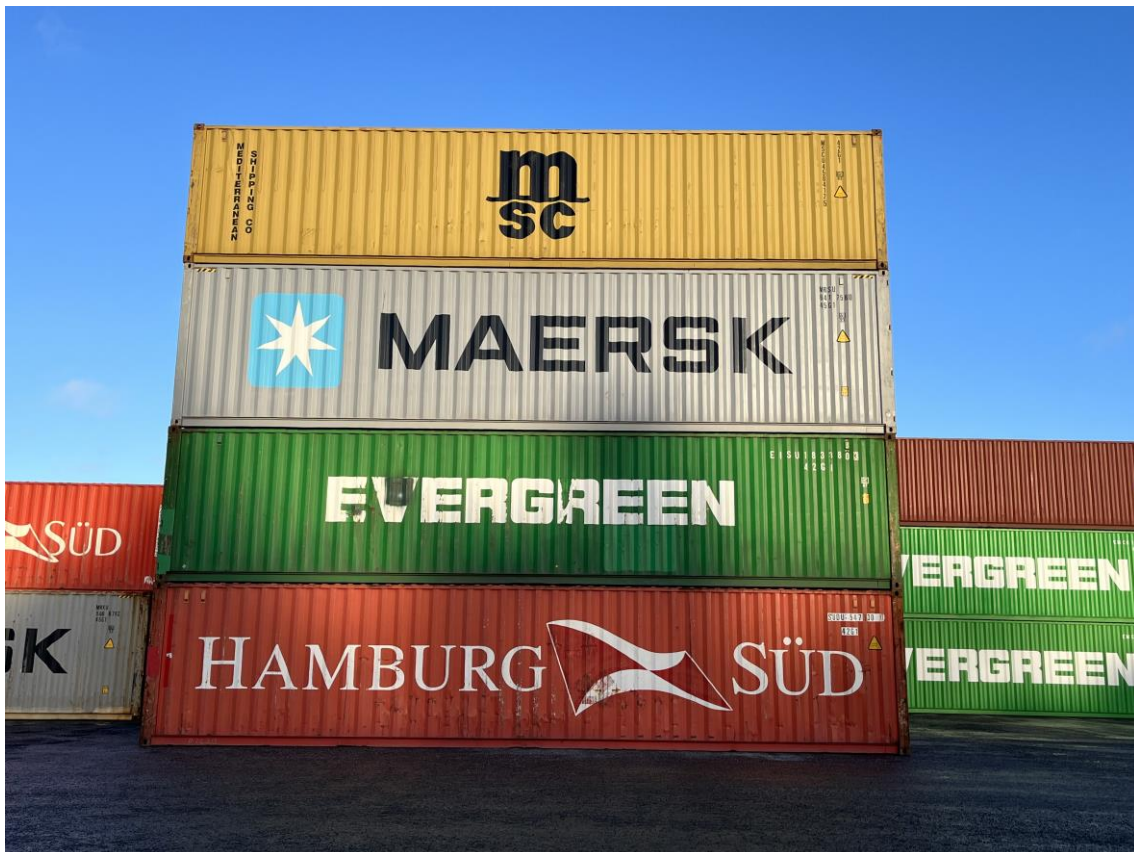


# RISE

SÄKERHET & TRANSPORT  
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**CHALMERS**  
UNIVERSITY OF TECHNOLOGY



## Empty Container Repositioning

Vendela Santén, Ceren Altuntas-Vural, Juan Pablo Castellon, Sara Rogerson, Violeta Roso and Ivan Sanchez-Diaz

RISE Rapport : 2023:82

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# Abstract

## Empty Container Repositioning

Although some movements of empty containers are needed due to imbalances between inbound and outbound goods flows in specific geographical areas, the transport of empty containers could be performed more efficiently. This report outlines results from the project “*Increasing transport efficiency through reducing positioning of empty containers*” performed during 2020-2023 by RISE and Chalmers, and financed by the Swedish Energy Agency. The purpose of the project was to contribute to increasing transport efficiency by understanding how empty container repositioning can be reduced and made more efficient in the Swedish transport system.

To provide increased understanding regarding current practices and possible improvement areas, the report describes empty repositioning of containers in the inland container transport, and highlights drivers and barriers to minimize and make empty repositioning more efficient.

Data on empty container movements in ports and by truck provide increased understanding of the current state. However, available data only offer partial views of empty container movements. Therefore, an empty trip model was constructed to help understand the proportion of containers that are transported empty between various origin-destination pairs, drawing on the Swedish road goods transport data from Trafikanalys. Several recommendations are made for how to improve data on empty container movements, for example differentiating between 20 and 40 feet containers.

Also, this report details strategies for either reducing the empty container repositioning or making it more efficient within the national transport system, with a focus on: a) increased reutilization of containers and b) an increased share of rail compared to truck transport. Reutilization involves matching import and export containers to a larger degree, for example facilitated by extended storage of containers, and also how demands in various regions can be matched more efficiently, where some geographical areas are import dominated and others export dominated.

The improvement potential in terms of cost and emissions have been calculated, simulating transport data in specific case studies. One simulation concerned reducing empty container repositioning locally, comparing the current situation with improvements in terms of street turns and extended storage given different collaboration levels. The extended storage scenario delivered the best results, as it significantly increased the likelihood of finding export cargo for an emptied import container. Another simulation considered empty container movements between Swedish inland terminals, identifying a large potential for both reutilization locally and triangulation between terminals compared to the current situation.

The report further outlines the outcome of a Multi-Actor-Multi-Criteria-Analysis, where opportunities to reduce empty container repositioning in the hinterland of a port were considered from several stakeholders’ perspectives: shipping lines, transport operators, inland terminals, forwarders, ports and cargo owners. The scenarios evaluated were a) *Time Flexibility*, where additional days were allowed to find matching export cargo for an emptied import container, b) *Container Sharing*, where implications of allowing

matching of containers of shipping lines in the same alliance were explored, and c) *Data Sharing*, where increased transparency regarding containers available for export in the inland was explored. The stakeholders preferred different scenarios, and details explaining their reasoning is provided.

Drawing on the insights regarding current practices and possible improvement areas, recommendations to industry and authorities are provided. Widespread collaboration between stakeholders is needed, even so, all stakeholders can take action to create better conditions for empty container repositioning. Smarter tools for planning is one example.

Key words: Container transport, Empty container, Repositioning, Street turns, Triangulation, Transport efficiency, Container substitution, Inland depot

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# 1 Introduction

This project is based on the results and research needs identified in the pre-study "Energy efficiency through increased load factor in sea transportation" (Santén et al., 2018) performed during 2017-2018. Based on quantitative data and a close dialogue with industry, the pre-study found that a too extensive empty repositioning of containers takes place today and that a reduced and more efficient empty repositioning of containers could lead to considerable energy savings from transports, through less unnecessary transport movements and better resource utilization of transport modes and containers.

A container is a standardized load unit used for container shipping for export and import flows of goods. In Swedish ports, there was a total of 1,3 million loaded TEUs handled in 2021 where the share of empty containers handled was 17% (Trafikanalys, 2023). Still, the containers are transported in the inland transport system, by road or rail, to the importers and exporters for unloading and loading their goods. Although some movements of empty containers are needed due to imbalances between inbound and outbound goods flows in specific geographical areas, there is potentially a large, but today unknown, efficiency potential by reducing the empty movements and using the most energy efficient transport mode.

Despite agreement among practitioners and researchers on existing unnecessary empty positioning, an overall picture of the empty repositioning of containers in the Swedish transport system is currently lacking. Individual actors who transport, handle or order transport of containers have visibility into their part of the system but lack the overall picture. Because the empty repositioning takes place with multiple types of transport modes and involvement of several actors (e.g. shipping companies, transport providers and hauliers), extensive data collection is required to get an overall picture at a higher system level. There are unfortunately major shortcomings in the publicly available official statistics for container transport (Trafikanalys, 2016a). The problem becomes even greater when multimodal transport chains are to be studied and analyzed both due to confidentiality conflicts but also due to lack of harmonization of traffic type-specific official freight transport statistics (Trafikanalys, 2016b)

Today's system is based on each shipping company optimizing its own container flow. The shipping companies' vulnerable competitive situation means that shipping companies rarely reposition competitors' containers. This means longer waiting times for cargo owners and difficulty in gaining access to the right number of containers on time. During the pandemic it was obvious that the disruptions in the logistics chains caused a scarcity in containers, and since the assets in terms of the shipping companies' containers are the basis for their transport service, the scarcity limited their available capacity.

In addition, another challenge is that the various actors involved in empty container repositioning have different interests and benefits associated with empty transport. For transport operators the empty positioning is a paid transport. Repositioning of empty containers can also be beneficial for shipping lines from a cost perspective, when capturing lucrative trade flows at another destination that needs capacity. However, from an environmental perspective, economically feasible transport flows might have higher than their solely economic costs. To understand how reduced empty repositioning can

be achieved, incentives and approaches based on the perspective of several actors needs to be studied as well as the repositioning process' emission improvement potential.

## 1.1 Purpose

The purpose of the project is to contribute to increasing transport efficiency by understanding how empty container repositioning can be reduced in the Swedish transport system and made more efficient through increased knowledge regarding the current situation and the potential for improvements. Empty container repositioning is quantified based on case studies in Sweden, and a better understanding of current approaches and possible improvement areas are created through qualitative data and analysis from different actor perspectives. The efficiency potential is calculated based on scenarios for improvements.

The project has the following goals:

- A qualitative description of how empty repositioning of containers takes place today
- Quantitative calculations regarding the current state of empty positioning of containers
- Three scenarios for reducing and/or streamlining empty positioning compared to the current situation
- Description of drivers and barriers for actors to minimize and make empty repositioning more efficient

## 1.2 Scope

The project studies empty container repositioning within the Swedish inland transport system, between the seaport and the container user (importer/exporter). Transport of containers using rail and road transport is included, where rail transport is achieved via a dry port/inland terminal in combination with a road transport to/from the container user.

The project does not focus on the port-to-port empty container repositioning which is a dominant problem that is studied in the literature but is mostly a shipping line concern. The inland transportation focus of this project relates to the efficiency and sustainability of the national transportation system.

## 2 Method

The research project was conducted between 2020 (November) and 2023 (June) with project management performed by SSPA/RISE (SSPA managed the project until December 2022 and RISE Maritime from January 2023 due to that SSPA was integrated into RISE from January 2023). Project partner was Chalmers University of Technology, Institution of Technology Management and Economics. Industrial involvement was central for the project and made through case studies, interviews with stakeholders and involvement of a reference group, which represented several actor groups (shipping companies, operators, forwarders, ports, terminals, cargo owners and authorities). The reference group met three times during the project period and several of the involved companies were also included in individual dialogues with the research team and supported the project with company and case specific data. In addition, a close collaboration was established with Chalmers University of Technology, Department of Technology Management and Economics through the Supply Chain Management master program. Several topics in relation to the work packages of the project were described and discussed with students resulting in the students becoming interested in the topics and conducting master theses. The results of the master theses served as valuable input to the project work. Further, two students were also employed for dedicated project work (outside of their theses). One student built new knowledge and analysis approaches (prior of the thesis), and another student continued working on the results after finishing the thesis. In both cases these results were obtained as part of the project work.

### 2.1 Research approach

The undertaken research was of both qualitative and quantitative nature. An overview of the project activities is shown in Figure 1 where the activities above the red timeline represents the qualitative work (lead by SSPA/RISE), and the activities underneath the red timeline the quantitative work (lead by Chalmers). Even if the project was structured around qualitative and quantitative research activities there was a strong collaboration between all research tasks in the project. For example, the qualitative descriptions provided input to increasing understanding of the system and the roles of the actors involved, which was important knowledge also for setting up the models in the quantitative assessments. Further, the results from the quantitative assessments showcased the actual empty container repositioning as well we the improvement potential, which was input to the qualitative discussions around strategies for improvements.

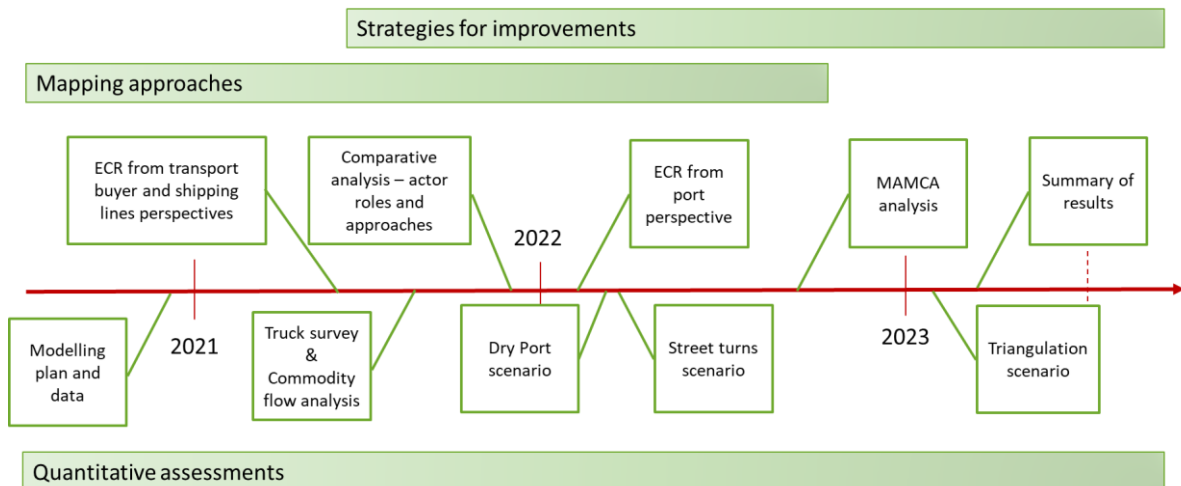


Figure 1: Overview of qualitative and quantitative project activities.

The qualitative work can be described as including two separate blocks 1) mapping approaches and 2) strategies for improvements. The block *Mapping approaches* provided input to the project goals: to provide a qualitative description of how empty repositioning of containers takes place today as well as the description of drivers and barriers for actors to minimize and make empty repositioning more efficient. Studies of the different perspectives were made, taking the shipping line and transport buyer (including both shipper and forwarder perspectives) as well as the port perspective. Interviews were made with all these actor groups, and transcriptions were analyzed with the qualitative analysis tool NVivo. The result provided input to identifying strategies and scenarios that were analyzed further both qualitatively as well as quantitatively. In chapter 3 Stakeholder in container transport, Barriers and drivers to ECR and General suggestions for improvements are described.

The next block, *Strategies for improvements*, had the main focus on assessing three separate strategies through applying a Multi-Actor-Multi-Criteria Analysis (MAMCA). A MAMCA is an established approach to better understand different actor perspectives on alternative scenarios. It has been applied successfully in different transport and mobility development projects to achieve decision support and reach consensus within and between actor groups, see e.g. Macharis and Baudry (2018). In this project a series of workshops were conducted to 1) select which scenarios to evaluate in the MAMCA, 2) identify assessment criteria for each actor group, 3) prioritize criteria and 4) evaluate alternative scenarios. The result of the MAMCA is presented in chapter 7 Stakeholder perspectives on scenarios to reduce empty container repositioning.

The quantitative assessments included two blocks 1) characterizing and modeling empty trips in Sweden and 2) assessing strategies for improvements. The block *Characterizing and modeling empty trips* aimed at improving the knowledge about the proportion of empty containers moved in the system and the attributes of those trips (e.g., industry, origin-destination). This first block focused on developing payload and empty trips models by integrating the data from the Commodity Flow Survey and the Truck survey, thus contributed to understanding the current state of ECR and is further described in chapter 4. The block *Assessing strategies for improvements* aimed at quantifying the benefits of implementing some of the strategies identified in the qualitative research (e.g., street turn, triangulation, alliances, extended storage time). The main performance indicators chosen for the assessment were empty containers distance traveled, energy

savings, emissions savings, and cost savings. The second block used data from two case studies:

- 1) A Dry Port and Street turn scenario
- 2) A Triangulation scenario

These two case studies are described in chapter 6 Quantitative assessments of strategies.

Based on the results from the qualitative and quantitative assessments, recommendations to industry and authorities were identified, described in chapter 8.

## 2.2 Dissemination

The project results have been disseminated in a number of conference presentations and through scientific publications. Also, the project has collaborated with Chalmers Supply Chain Management master program, where identified relevant master thesis topics has resulted in seven master theses within the area of empty container repositioning, which also provided input to the whole research project.

### **Conference presentations:**

- Santén V., Rogerson S., Roso V., Altuntas-Vural C. (2021). "Strategies to reduce empty container repositioning". Presentation at the Swedish Transportation Research Conference (online), October 2021, Malmö Sweden.
- Roso V., Altuntas-Vural C., Rogerson S., Santén V. and Finnsgård C. (2021). "Empty container repositioning – Matching the barriers with possible solutions". Presentation at 29th Conference of the International Association of Maritime Economists (online), November 2021, Rotterdam Netherlands.
- Roso, Altuntas Vural, Santén, Rogerson, Finnsgard, Hvolby, Steger-Jensen and Thorsen (2022). "Empty Container Repositioning". Presentation at NOFOMA conference, June 2022, Reykjavik Iceland.
- Santén V., Rogerson S., Roso V., Altuntas-Vural C., Kalahasthi L., Castellon J., Sánchez-Diaz I. (2022). "Reducing empty container repositioning: The potential of street turns". Presentation at NOFOMA conference, June 2022, Reykjavik Iceland.
- Rogerson S., Santén V., Roso V., Altuntas-Vural C., Kalahasthi L., Castellon J., Sánchez-Diaz I. (2022). "Ökad transporteffektivitet genom minskad tompositionering av containrar". Presentation at Transportforum Conference, June 2022, Linköping Sweden.
- Castellon JP., Sanchez-Diaz I., Roso V., Altunats-Vural C., Rogerson S., Santén V. and Kalahasthi L. (2023). "How to reduce inland empty container movements? An assessment of shipping lines collaboration and empty container repositioning strategies in a Dry Port in Sweden". Presentation at Transportation Research Board (TRB) conference, January 2023, Washington USA.
- Roso V., Altuntas-Vural C., Hagelin S., Knutsson A., Rogerson S. and Santén V. (2023). "Empty container repositioning in Port of Gothenburg hinterland". 10th International Maritime Science Conference, May 2023, Solin Croatia.
- Kalahasthi L, Castellon JP, Sanchez-Diaz I, Roso V, Altunats-Vural C, Rogerson S and Santén V (2023). "Truck Container Movements in Sweden: Payload and Empty Trip

Modeling”. Presentation at World Conference on Transport Research (WCTR) conference, July 2023, Canada.

### **Scientific publications:**

- Roso, Altuntas Vural, Santén, Rogerson, Finnsgard, Hvolby, Steger-Jensen and Thorsen (2022). “Empty Container Repositioning”. NOFOMA conference proceedings, June 2022, Reykjavik Iceland.
- Santén V., Rogerson S., Roso V., Altuntas-Vural C., Kalahasthi L., Castellon J., Sánchez-Diaz I. (2022). “Reducing empty container repositioning: The potential of street turns”. NOFOMA conference proceedings, June 2022, Reykjavik Iceland.
- Castellon, J. P., Sanchez-Diaz, I., Roso, V., Altuntas-Vural, C., Rogerson, S., Santén, V., & Kalahasthi, L. K. (2023). Assessing the eco-efficiency benefits of empty container repositioning strategies via dry ports. *Transportation Research Part D: Transport and Environment*, 120, 103778.
- Kalahasthi L, Castellon JP, Sanchez-Diaz I, Roso V, Altunats-Vural C, Rogerson S and Santén V (2023). “Truck Container Movements in Sweden: Payload and Empty Trip Modeling”. World Conference on Transport Research (WCTR) conference proceedings, July 2023, Canada.

### **Master theses:**

- Frändberg E., Luhar R. (2020). Capacity utilisation in liner shipping. Master thesis in Supply Chain Management 2020. Chalmers University of Technology.
- Hagelin S., Knutsson, A. (2020). Reducing Unnecessary Empty Repositioning of Containers: Transport Efficiency on a Regional Level in Sweden. Master thesis in Supply Chain Management 2020. Chalmers University of Technology.
- Hellekant R., Rudal, M. (2021). Activities and reduction strategies of empty container repositioning – A regional and inter-regional perspective to the liner shipping industry in Sweden. Master thesis in Supply Chain Management 2021. Chalmers University of Technology.
- Karlander A., Tegbrant, A. (2021). Improved transport efficiency through reduced empty positioning of containers. Master thesis in Supply Chain Management 2021. Chalmers University of Technology.
- Johansson S., Willisroft, L. (2022). Reducing Unnecessary Empty Container Repositioning: The Role of Seaports and Inland Terminals. Master thesis in Supply Chain Management 2022. Chalmers University of Technology.
- Xu H., Ibrahim A. (2022). Assessing the Economic and Environmental Effects of Dry Port and Triangulation Transportation on the Empty Container Repositioning Problem -A Case of Inland Container Transport System in Sweden. Master thesis in Supply Chain Management 2022. Chalmers University of Technology.
- Kowshik, R. (2023). Optimizing Empty Container Repositioning at Inland Terminals Using Data Analytics to Make an Informed Decision for a Seaport in Sweden. Master thesis in Supply Chain Management 2023. Chalmers University of Technology.

### 3 Qualitative description of inland container transport

The empty container repositioning (ECR) process in the hinterland includes multiple actors. To understand the process, first the different process steps need to be mapped as well as the actors that are involved. Thereafter, the activities of these different actors in each process step need to be investigated to understand the roles and interactions.

The need for an empty container in the inland transport chain is triggered by the booking order received from an exporting company. This demand can be satisfied in two different ways. First, the empty container can be delivered from the available stock in that certain country or region. This requires a short-term storage of empty containers at an inland depot or a port area until demand occurs. Furthermore, this is dependent on the availability of the quantity and the type of the empty unit that is demanded. In case of unavailability, the second positioning process is triggered. In this case, the required empty container inventory is positioned from another port on the shipping line’s own vessels or from a nearby inland destination which requires inland transportation. In rare cases, it is also observed that shipping lines can exchange containers between each other for an exceptional booking or shippers use their own containers. When an inland leg is included involvement of actors such as ports, inland terminals, transport operators providing road, rail or inland waterway transportation, freight forwarders or logistics service providers (LSPs), importers and exporters, is required.

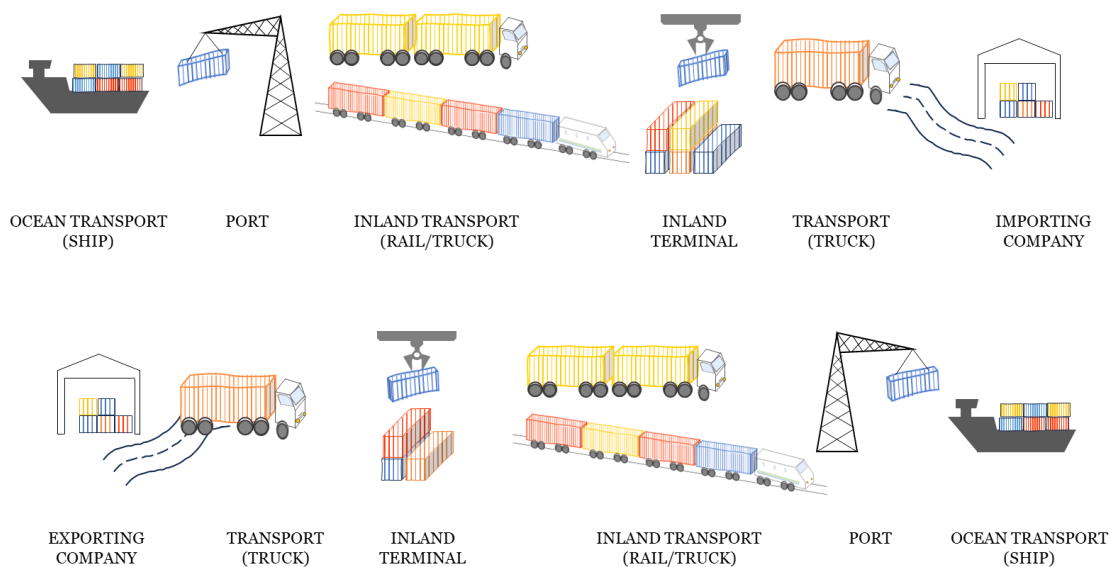


Figure 2: Transport flows for loaded containers (illustration by Sara Rogerson)

Figure 2 illustrates the flow of loaded containers. Import containers arrive in the port, are transferred to rail or truck for inland transport. Often, the train stops at an inland terminal where the containers are transferred to truck for the final leg to the importing company. Similarly, an export company sends a loaded container by truck either directly

to port, or via an inland terminal where it is transferred to rail for the transport to port. In the port containers are loaded onto container vessels for further transport. There are several variations to this process, e.g. stuffing and stripping of the containers being performed at the terminal and the leg closest to importer or exporter performed by conventional trucks.

## 3.1 Stakeholders in container transport

The empty container repositioning process includes many actors who are aligned across the maritime supply chain. These actors need to exchange services or sometimes collaborate in order to manage this process in an efficient and effective way. The global ECR problem is between the ports that individual shipping lines operate, for example between ports in Asia and Europe. On the other hand, the inland ECR problem, which is the focus of this report, is rather a local or regional problem and includes also the inland transportation actors.

### 3.1.1 Shipping lines

The main actor group is composed of the owners or the lessors of the empty container, i.e. shipping lines. Shipping lines have a special position in the transport chain as their ownership role enables them to have a global overview of the system, control the flows of empty containers and define the terms in the chain. However, this also creates a significant inventory holding cost for them. Empty containers are the second inventory type that the shipping lines need to manage; the first is the ship space itself. Being unitized and standardized, managing this inventory is a big problem for many global shipping lines who are in need of different types, sizes and quantities of these containers at different parts of the world due to trade imbalances. In Sweden, a similar imbalance exists between ports and regions. The shipping lines that were involved in this study underlined the imbalance in Gävle, Åhus, Stockholm and Gothenburg. Gävle and Åhus are dominated by export cargo but low in import cargo so they require a lot of repositioning. This is the opposite for Stockholm where import volumes exceed export. In Gothenburg, although the volumes are relatively balanced, there is a container type mismatch where the import is 20ft dominated and export is 40ft dominated. The inland positioning of empty containers is handled by rail and road transportation. When international positioning is needed, the equipment planners in shipping lines demand empty containers from neighbouring ports such as Rotterdam and Hamburg.

### 3.1.2 Ports and inland terminals

The seaports' role in the transport chain is to facilitate transport for cargo owners, their representatives or the shipping lines. They might provide other services related to the container such as stuffing, destuffing, repair and maintenance, fumigation, weighing and most importantly storage. Some ports provide empty container storage services in dedicated depot areas however port land is expensive and limited. This increases the cost of keeping empty container inventory at these facilities. Seaports' main role in ECR is loading or unloading empties to/from ships, short-term storage of this inventory and transshipment of these units to their destinations either with intermodal or unimodal transportation.

Many seaports are connected to different types of inland terminals to secure their hinterland connections, to extend their presence and to relieve the pressure on their limited capacity at the shore. These inland terminals provide a variety of services depending on their characteristics. Some are dedicated to a large cargo owner, and some function as a hub for different cargo owners around a certain region. They are used as transshipment hubs for empty containers and, in some cases, as empty container depots where empty containers can be stored until an export demand is received. If the seaports are connected to these inland terminals via rail, then this has a significant positive impact on the eco-efficiency of empty container movements.

The involved seaports and inland terminals in this project stated that their role in ECR is rather limited as they do not have the control over the flows. However, the results of the project indicated that by providing temporary storage services for empty containers in collaboration with the shipping lines, these terminals can have a significant impact in increasing the efficiency of the ECR process.

### 3.1.3 Transport operators

Transport operators perform the actual positioning of the empty containers in the hinterland. They can be rail, road or inland waterway operators depending on the availability of the infrastructure in a certain region. In Sweden, they are mainly rail or road operators. They can provide the positioning service directly to the cargo owners if the contract is a merchant haulage. They can provide the service to freight forwarders or LSPs in case they act as subcontractor to these actors. As a third alternative, they can also handle the service on behalf of shipping lines if the contract is a carrier haulage. Their role is important because they are the ones who are the closest to the demand information and they own the inland transportation capacity. The inclusion of these actors into the ECR information flows can contribute significantly to the eco-efficiency of the overall process.

### 3.1.4 Freight forwarders and LSPs

These actors act as brokers between cargo owners and shipping lines. In case they own or operate their own assets, the freight forwarders or logistics service providers (LSPs) can also act as transport operators. Many cargo owners work with these actors for the inland container transportation and logistics services. Hence, they have a good knowledge of the market and the ability to position emptied containers directly to where demand occurs. With an effective information sharing process, these actors can help to improve the eco-efficiency of ECR process but recent developments in the market indicate that the shipping lines tend to increasingly extend their presence in the inland transport chain. They have started providing majority of the services that have traditionally been provided by freight forwarders or LSPs to the cargo owners. This creates a tension between these two important actors.

### 3.1.5 Cargo owners

Cargo owners are composed of importers (also referred to as consignees) and exporters (also referred to as consignors). Export demand in a region derives the demand for ECR and import demand defines empty container availability. Like other parts of the world, also in Sweden, some of these actors work directly with shipping lines while some work

via LSPs or freight forwarders. Actors such as shipping lines, forwarders, LSPs or transport operators build their empty container demand forecast on the information on importer and exporter cargo flows. An improved information flow between importers, exporters and other transport chain actors has significant potential to increase the eco-efficiency of ECR.

## 3.2 Barriers and drivers to ECR

There are several driving forces behind ECR as well as several barriers. Considering the multi-actor structure of ECR in the hinterland, it is important to understand these driving forces and barriers from the multiple perspectives of these actors. Some of these drivers and barriers might be more important for some actors but rather negligible for others. However, in the end, it is necessary to understand and eliminate the barriers if desiring to improve the ECR process for the whole inland transport chain. In this section, first the drivers will be summarized and then the barriers outlined from several actors' perspectives.

### 3.2.1 Drivers

Overall, the drivers to reduce ECR can be summarized under financial and environmental drivers. An empty container is similar to an idle inventory. It requires space, maintenance, capital and incurs depreciation cost. In addition, it is available capacity that is unutilized. Hence, all shipping lines try to minimize the ECR costs or optimize their forecasting abilities. Furthermore, even though the other actors such as ports, inland terminals or hauliers still generate revenues by providing services to store or move empty containers, the revenues coming from full containers are always higher. Globally, approximately 25% of the containers in the maritime container flow are empty which is incurring large costs for the shipping lines where substantial cost savings can be achieved if ECR is reduced (Kolar et al., 2018).

In addition to the financial drivers, reduction of empty container movements results in reduction in emissions (Braekers et al., 2011) and the improvement of environmental performance for the involved actors. Despite this potential impact, in this project, it was observed that this was not the main motivation for many of the involved actors. Their environmental sustainability activities were mostly focusing on the improvements in the main transport mode or infrastructure. ECR was mostly perceived from the financial perspective. However, some actors mentioned that due to changing customer (shipper) requirements, ECR can function as a good method for emission reductions and increase the attractiveness of the entire transportation service for the customers. Other drivers that result from financial and environmental gains are increased competitiveness, better capacity utilization, better resource utilization (labour or containers) and better return on investment.

### 3.2.2 Barriers

The driving forces that are summarized above are not new findings. However, despite their existence and recognition, they are still not fully utilized due to conventional ECR processes and prioritization of other stakes. Hence, it is important to understand,

categorize and investigate the different barriers that are relevant for different actors to a different extent, to eliminate them and improve ECR processes and enhance efficiency.

### **Structural barriers**

ECR cannot be eliminated completely since some movements of empty containers are needed due to demand patterns, i.e. imbalances do exist between inbound and outbound goods flows in specific geographical areas. This is referred to as structural imbalances in container shipping and the biggest barrier to reduce ECR. Nearly all of the actors referred to the trade imbalance in Sweden where despite the relatively good balance between exports and imports in general, there exists demand imbalances between regions and ports. Some ports, such as Halmstad, are import dominated, e.g. due to the distribution centers located nearby. Other ports, such as Åhus are export dominated due to manufacturing facilities located nearby. The imbalance in population density in Sweden is also another reason behind this barrier.

In addition to this structural imbalance, there is also the technical imbalance where container types or cargo types do not match. This is based on various types of containers existing, including different sizes, and also varying cargo characteristics, e.g. dimensions or the need for cooling. As an example, Port of Gothenburg in Sweden, imports more 20ft containers but exports 40ft containers. Some containers that move cargo such as scrap or waste cannot be reused for clean cargo exports such as textiles or food.

### **Operational barriers**

Shipping lines are the ones controlling the movements of empty containers, and depending on how they formulate and follow their own strategies and operational practices, ECR will be affected negatively and/or positively (Song and Dong, 2015). Although ECR can be reduced by better demand forecasting, many shipping lines do not have the ability to track and trace all of their container fleet, particularly in the inland destinations. This lack of visibility exacerbates the structural and technical imbalance in the system.

### **Financial barriers**

Furthermore, sometimes it is economically neglectable to move empty containers around the world due to higher profitability levels at certain trades. In such cases, shipping lines and the other actors do not prioritize ECR as a strategy. This creates a vicious cycle because when the freight rates and profitability are high, all shipping lines invest in more containers in order to increase their market share in these trades. This creates a surplus in the system and again exacerbates the imbalance conditions. One example comes from the Covid-19 pandemic, where freight rates increased particularly from Asia to Europe following a higher demand than available container capacity. In light of this, emptied containers were extracted from Sweden to Asia immediately, without allowing them to wait for an export booking, because of the potential of financial gains for shipping lines in getting new cargo from Asia.

### **Market-related barriers**

Finally, some market-related factors also create additional barriers to reduce ECR. There are many actors who are involved in the door-to-door container shipments. Effective ECR requires a high degree of collaboration between these actors but when the number

of actors is high then it is more difficult to achieve collaboration. Also, transactions in container shipping are highly dependent on service contracts where the parties commit certain quantities during a period of time. When a shipping line guarantees certain number of containers to a shipper, then they have to provide those containers whenever they are needed. This also hinders the ability to reduce ECR and expedite the repositioning process.

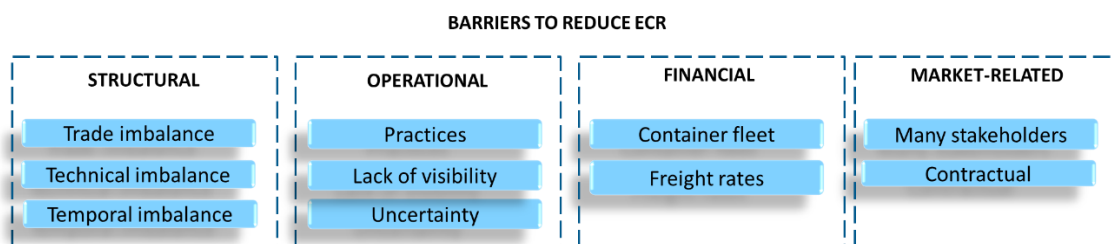


Figure 3: Overview of barriers to reduce ECR

### 3.3 General suggestion for improvements

There are several potential solutions for reducing ECR, pinpointed by the actors that provided input during the project and also in earlier literature. Below in Figure 4 these potential solutions have been grouped. The two most promising solutions are street turns and inland depots, which concern ways to reduce the distance through changes to routes or locations. There are also a number of improvements possible with regards to the container. Further, there are various ways that potentially could reduce ECR through regulations, agreements and ownership. Finally, potential improvements also include new ways of coordination, described under the other headings as it facilitates other improvements.. The different solutions are explained in more detail below, with most focus on street turns and inland depots, which were identified as most promising for the scope of this project.

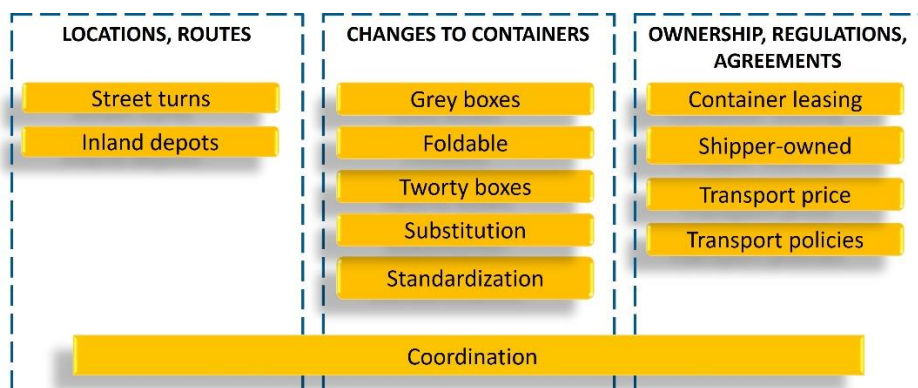


Figure 4: Overview of improvement opportunities

## **Changes to locations or routes**

Street turns are a way to transport containers between an importer and exporter without using a container terminal in between (Braekers et al., 2011). By letting other actors within the container transport chain know when empty containers are available, this will reduce the number of movements for an empty container and consequently reduce ECR. Tight time windows, finding collaboration partners and ownership of containers as three major challenges to implement street turns (Braekers et al., 2011). Hence, the suggestions to improve and increase street turns are extended free-time, increased collaboration between actors, container sharing between shipping lines and transparent information sharing with the help of digital tools between transport chain actors. These digital tools such as sensors and internet-based tracking systems are expected to increase visibility which is much required for reduced ECR.

Another way to reduce ECR is to increase the use of inland depots for keeping empty containers. Such a solution can shorten the distances that empties travel within a country and increase the ability to match a container demand from a local depot.

## **Changes to containers**

Some of the solutions are related to the container design. Grey boxes stand for generic containers that do not have any brand names on them. Such grey boxes act as a common container fleet and can be shared by the shipping lines. The shipping line representatives state that although this is a very effective solution in theory, it is not desirable to apply this in practice as the containers are also a marketing communications tool for shipping lines. Furthermore, every shipping line manages their own container fleet. Having a common fleet requires having a common manager for this fleet which would create a competition problem in this highly oligopolistic industry. Foldable containers and twenty boxes are among other container design solutions. Foldable containers are designed with walls and doors that can be lowered inwards together with the roof (Konings, 2005) and can be stacked on top of each other when they are folded, thus can reduce the number of transports to move empty containers. However, the participants in this project stated that this type of design would result in difficulties in handling, lower durability and higher handling cost. Twenty boxes, on the other hand, are 20ft containers designed to be combined, creating 40ft containers (Malchow, 2015). Again, although it seems like an effective solution to reduce technical imbalance in theory, in practice they have similar risks as foldable containers.

Container substitution can possibly mitigate the problem with technical imbalance. By asking customers if they are willing to change their demands and use a container type that is available, the technical imbalance can be reduced. However, this requires increased communication and collaboration between the customer and the company responsible for the transportation of goods. Changing out the container type can also influence the space needed onboard the vessel (e.g. using high cube containers).

## **Changes to ownership, regulations or agreements**

As a potential solution to the ECR problem, container leasing could affect the barrier container fleet size since the fleet size consists of both owned and leased containers. Having a fleet of entirely leased containers would, from an ECR perspective, reduce a transport company's need to perform ECR. However, as already pointed out by Braekers

et al. (2011), container leasing might just transfer ECR from one actor to another, leading to sub-optimization in the container transport chain. To ensure the effect on owning versus leasing containers, further research must be done. Furthermore, container leasing might mitigate uncertainty. In order to cover up for unexpected shortages of containers, shipping lines can lease containers from leasing companies. In that way, empty containers will not have to be retrieved before goods can be transported, which ultimately would help reduce ECR. The leased containers would in this example be used as a safety stock.

An increased transport price would potentially increase the income for a company, as long as customers still buy the service. This increased income can be spent on new investments to reduce ECR and consequently, this is a solution to manage the barrier operational practices. However, it can also be discussed that an increased transport price would make ECR more economically feasible. By introducing penalty fees for ECR, transport policies have the potential of reducing unnecessary ECR. This would be a way of forcing actors to manage the barrier strategies and operational practices, in order to make them move empty containers as short distances as possible.

## 4 Current state of ECR in Sweden

This chapter describes the current state of ECR in Sweden, which is based on the first block of quantitative assessments, characterizing and modelling the empty trips. First, a broader picture of the imbalances in export and import flows through the ports is provided as a start.

### 4.1 Imbalances in demand and empty container handling in ports

Central nodes for container movements in Sweden are the ports. To get an overview of the container flows through the Swedish ports, port data from 2022 (Trafikanalys, 2023) has been summarized based on laden and empty TEUs, unloaded and loaded at the geographical areas of container ports (see Table 1). One geographical area may include several ports, such as Malmö-Helsingborg, which include both ports. By using the geographical areas (and not each single port) it is possible to get an overview and compare the flows at a national level including all container flows, both the major container ports and minor flows using other ports.

The geographical port areas have varying demand of empty containers, which depend on the imbalances comparing import and export container volumes. A well-balanced import and export port area should in theory have a low share of empty containers moved through the port since the import containers can be re-utilized for the export flows. As has been discussed in previous chapters the equation in practice is not that straight forward and several Table 1, barriers exist towards re-utilizing containers, such as technical and contractual barriers (see 3.2).

As can be seen in, Göteborg is the port with by far highest container volumes. Göteborg is the port area with the largest import and export flows in Sweden and with a rather good balance between them, only slightly predominantly export (87% balance ratio<sup>1</sup>). The predominance in export means there is a need for empty containers to be moved to the geographical area for being used in the export flow. This is also noted in the figures with 105 280 unloaded empty TEUs during 2022. 49 912 empty TEUs were still loaded for being shipped from the port of Göteborg which reflects the TEUs that could not be used for the export flow. As mentioned above, this may happen for several reasons (such as technical and contractual barriers).

Another well-balanced area is Halmstad-Varberg (89% balance ratio), also slightly predominantly export. Uppsala-Eskilstuna area have a rather good balance in comparison with other geographical areas as well (116% balance ratio), however some overweight in import flow.

The second largest geographical container port area is Malmö-Helsingborg in terms of number of TEUs handled and this area is import dominated (153% balance ratio).

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<sup>1</sup> The balance ratio is a measure of the relationship between unloaded and loaded TEUs in a specific port area (with cargo). 100% balance ratio means that there is a balance between import and export containers.

Southern east-coast, which includes the port of Norrköping, is the third largest geographical container area, also with an overweight of import (145% balance ratio).

On the other hand, there are a number of export dominated geographical port areas: Karlskrona-Trelleborg (12% balance ratio), Hudiksvall-Gävle (35% balance ratio) and Umeå-Sundsvall (37% balance ratio). This pattern has a natural explanation in the trade and the needs from specific industries in the geographical port areas. In addition to the data in Table 1, Figure 5 illustrates the trade imbalance in Swedish ports 2022, by showing ratio between the difference of unloaded and loaded laden TEUs and the total number of laden TEUs handled.

Table 1: Laden and empty TEUs loaded and unloaded in geographical port areas 2022 (based on Trafikanalys, 2023)

Port area	Laden TEUs (with cargo)			Empty TEUs (without cargo)			Share of empty
	Unloaded in ports	Loaded in ports	Balance ratio (Unloaded /Loaded)	Unloaded in ports	Loaded in ports	Total Empty	
Karlskrona-Trelleborg	794	6 371	12%	4 190	404	4 594	39%
Hudiksvall-Gävle	28 057	80 834	35%	67 234	4 996	72 230	40%
Umeå-Sundsvall	1 116	3 014	37%	823	566	1 389	25%
Stenungsund-Strömstad	2 273	3 945	58%	1 126	285	1 411	18%
Göteborg	336 976	387 221	87%	105 280	49 912	155 192	18%
Halmstad-Varberg	17 460	19 552	89%	4 956	4 784	9 740	21%
Uppsala-Eskilstuna	9 043	7 784	116%	512	1 486	1 998	11%
Southern East-coast	60 603	41 905	145%	7 929	16 206	24 135	19%
Haparanda-Skellefteå	2 621	1 732	151%	1 395	1 522	2 917	40%
Malmö-Helsingborg	140 858	91 929	153%	12 111	49 763	61 874	21%
Norrköping-Nynäshamn	18 238	7 771	235%	895	12 124	13 019	33%

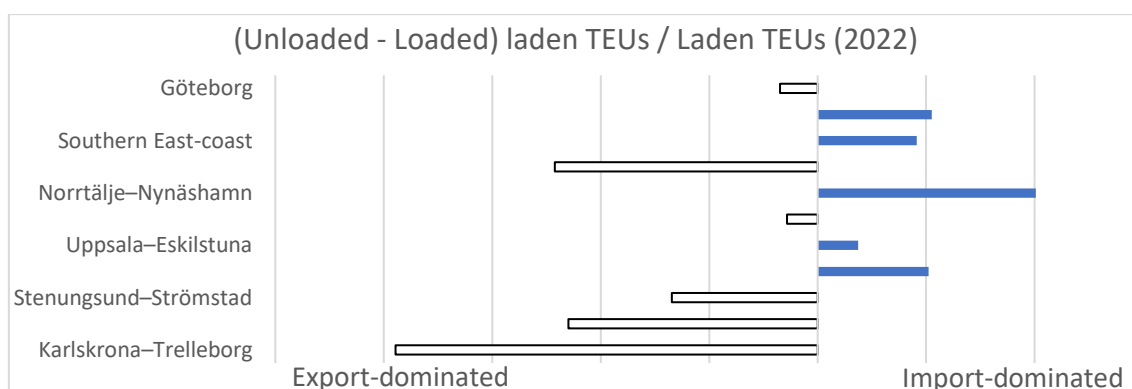


Figure 5: Illustration of the level of export and import dominance in the geographical port areas

If taking a closer look at the figures of empty container movements in relation to the import and export container goods flows we can see that there is not an exact match of containers being moved into (unloaded) and out of (loaded at) the port area. Since the containers are moved in the inland transport system to the consignee and consignor, the export flow can also take a new route, through other ports (national or international) for the next mission.

There is a total positive net flow of containers (laden and empty) into the geographical port areas (in total 30 384 TEUs). These containers are not passing Swedish ports for export. Instead, these containers may be transported by road and rail to ports in northern Europe for example.

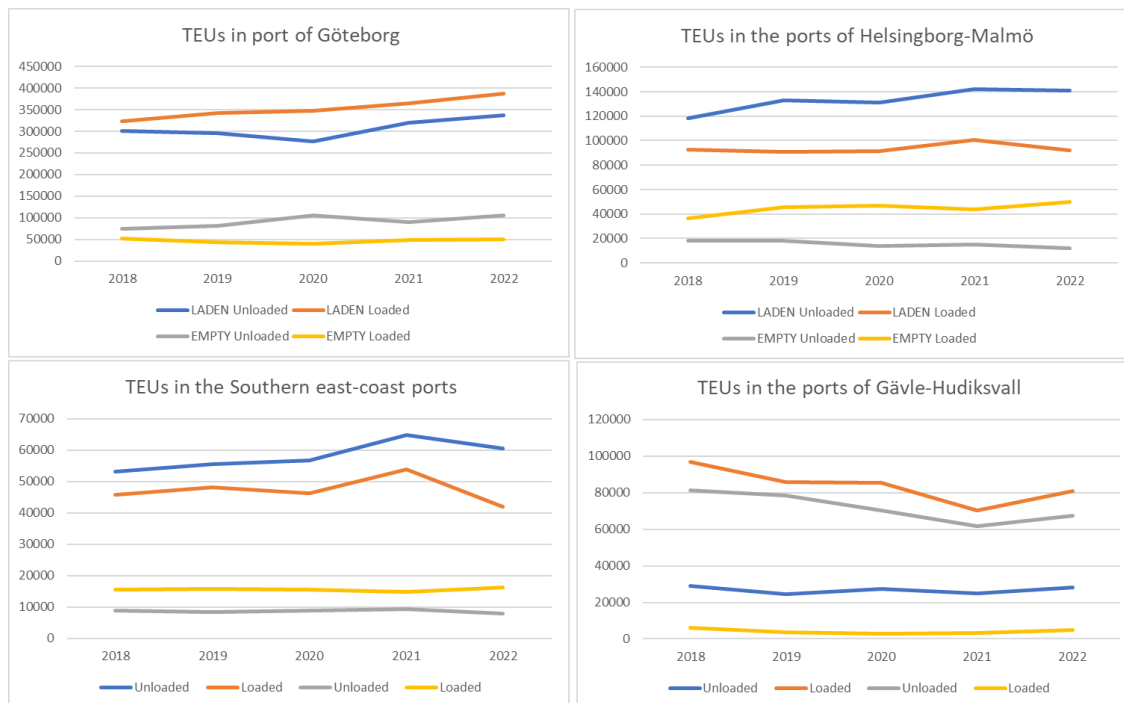


Figure 6: TEUS in Swedish ports 2018-2022

Based on additional data from Trafikanalys (2023), Figure 6 above shows the development over the past five years in TEUs loaded and unloaded in some of the largest Swedish container ports. There is a steady positive trend in the port of Göteborg handling a larger amount of total TEUs 2022 compared to 2018. The ports of Gävle-Hudiksvall has instead a decrease in number of TEUs moved during the period. There is an interrelation between the ports, since goods flows can take new routes with new logistics solutions inland. For example, the port in Göteborg collaborates with inland terminals in the northern part of Sweden with rail connection. One possible explanation for these trends is that more volumes use inland terminals and rail system from/to port of Gothenburg instead of closest port.

## 4.2 Data sources and gaps

Despite the importance of reducing empty container movements for a more efficient and sustainable transportation system, there is no accurate data describing the movements of empty containers. For the Swedish transport system, the datasets available offer partial views of the journey of empty containers. As shown in the previous section, Swedish ports register and inform about the number of TEUs handled at each port including empty containers. Trafikanalys collects good data about the production and attraction of freight flows both for Sweden and for imports and exports as well as which share is moved by rail thanks to the Commodity Flow Survey (CFS) and the corresponding freight generation and mode split models. It is noteworthy that the

models based on the CFS only provide an estimation of freight flows by mode and not on the number of containers moved across the country. Moreover, the transport modes available in the CFS data are limited to either road, rail, shipping, and air or any combination of the above four modes, which do not differentiate between containerized and non-containerized cargo. The complexity of modeling empty container movements is due to their existence in three modes, via truck, rail, and shipping, where each mode could have different shares of containerized cargo. Currently, truck is the only mode for which partial information on container movements is available through Swedish road goods transport data collected by Trafikverket from the truck operators every year between 2016 and 2019. This data provides a reasonable sample of all truck movements, including containerized trucks and empty container movements. Although this sample represents a significant part of registered trucks (~14%), the main drawback is that it is disconnected from the CFS, which means that it is not used to expand/ estimate the overall number of container movements, particularly empty container movements at the national level.

In essence, the Swedish road goods transport data could be better used to estimate national-level container movements by road if it could be effectively combined with the CFS data, assuming the future CFS data could provide an estimate of containerized truck cargo movements by tons between Origin and Destinations (OD). The integration with CFS data is feasible by estimating two models from the road goods data: 1) a payload model which converts the tons of cargo transported to the number of loaded truck containers, and 2) an empty trip model to understand the proportion of containers that are transported empty between various OD pairs, and industry sector. Thus, a payload model and empty container trips model have been developed using the Swedish road goods transport data obtained from Trafikanalys for four years from 2016 to 2019 (23). Sweden has around 84,000 registered trucks with maximum load weight larger than 3.5 tons and driven for about 2,900 million vehicle kilometers in 2019 (26, 27). The road goods transport data is a valid sample for modeling and analysis of payloads and empty trips as it is based on a mandatory annual survey from approximately 12,000 Swedish registered trucks (~14%) including container and non-container traffic. After segregating the container flows from the total truck trips, the dataset is divided into two parts: loaded and empty containers (see Figure 7). Less than one percent belongs to international trips.

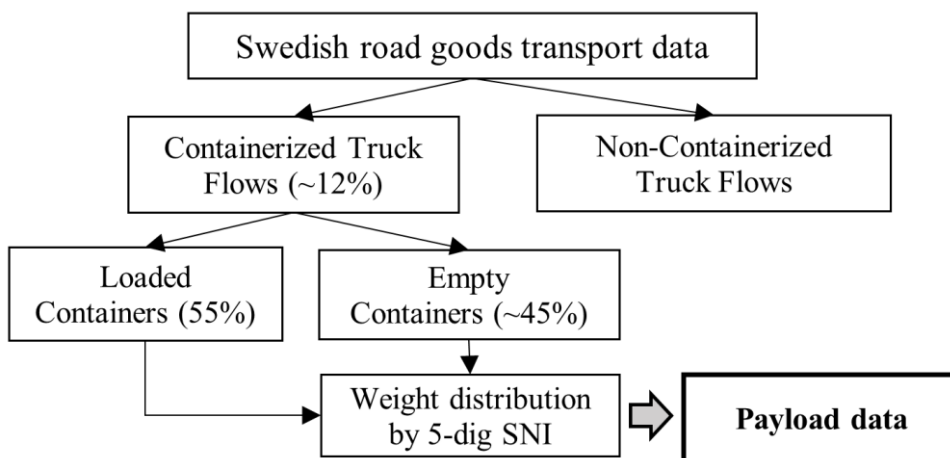


Figure 7: Payload Data Preparation

## 4.3 Modelling approach

Estimation of freight demand at regional and national levels plays a key role for the public sector and policy makers in effective planning of policies and infrastructure developments to achieve intended benefits—including reductions in total vehicle distance travelled, pollution, emission, traffic congestion and noise. Despite the need for such knowledge in practice, national freight modeling is limited to the estimation of demand in terms of weight of cargo, and mode choice modeling in a few countries. One of the key predicaments to freight modeling is the lack of data with proper variables at required level of details. For instance, the Commodity Flow Survey (CFS) dataset which is known as the biggest source of national freight data in the US and Sweden has its own limitations in estimating freight demand. The CFS data were used to develop econometric models to estimate the weight of freight production and mode choice between truck and rail in the US. Similarly, the freight demand models for Sweden based on the CFS data include, the most comprehensive freight model popularly known as SAMGODS as well as a stochastic logistic model. One of the key challenges with these existing national demand models are associated with the evaluation of actual impacts of freight transportation on the infrastructure network (truck, rail, waterways, etc.) in terms of vehicle flows. Because the demand models are typically commodity-based which gives results in weight of cargo instead of number of vehicles transported.

The conversion of commodity-based to the trip-based freight demand model is complex due to two main reasons: i) lack of payload model to estimate the loaded trips and, ii) assessing the empty vehicle trips. Figure 8 depicts the process of using the payload and empty trip models to convert commodity flows into vehicle flows between an origin and a destination. The payload model estimates the loaded vehicle trips from the cargo flows. Whereas the empty trip model provides an assessment of total vehicle trips including the loaded and empty trips. The payload is the weight of cargo a vehicle carries i.e., total weight of the vehicle excluding the empty weight, which is often less than the designed capacity. Moreover, there are several combinations of modes and vehicle types that could transport given cargo between an origin and a destination. Though the existing mode and vehicle choice models at national level provide a way to estimate the shares in tons, the number of vehicle flows in each mode is still difficult to obtain. The reason is that the number of loaded vehicles required to carry a given weight depends on several intricate factors e.g., type of cargo, density, packaging, vehicle capacity. Hence, a payload model is useful in converting the cargo flows into the loaded vehicle flows by considering as many factors as possible.

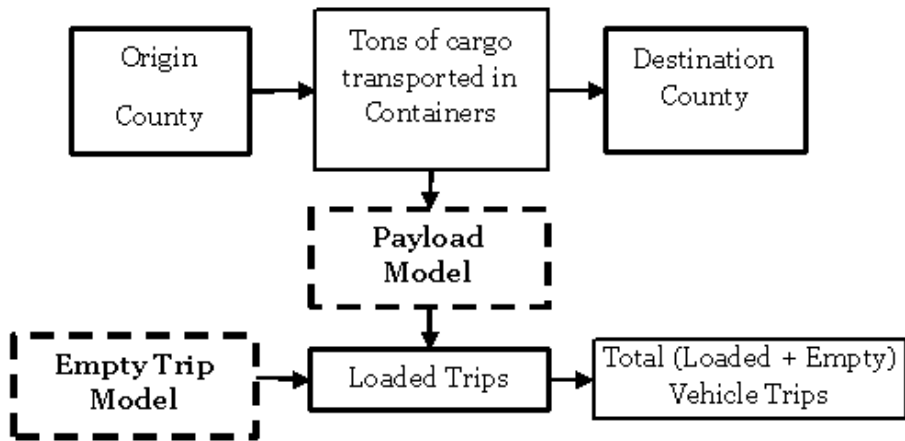


Figure 8: Schematic of Estimating Container Vehicle Flows

## 4.4 Payload Data

The data preparation for the payloads is previously shown in Figure 7. The payload is the weight of cargo carried inside a container excluding the weight of the empty container. The road goods data do not have the payloads. However, the weights of the loaded containers (i.e., payload+ weight of empty container) are available. Hence, the payloads should be obtained from the loaded container data by subtracting the weights of the empty containers.

$$\text{Payload} = \text{Weight of loaded container} - \text{Weight of empty container}$$

Unfortunately, the road goods data provides the weights of loaded containers and empty containers without differentiating the type of container (20 or 40 ft). It is practically impossible to figure out if a loaded container is 20-ft or 40-ft, and the weight of an empty container carrying the cargo. Hence, an approximate estimation of empty container weights was imputed to the load container data to obtain the payloads.

Different industry sectors handle different types of cargo, different transport requirements and different logistics practices. Moreover, while overall demand can have a big imbalance within a region, it is possible that when one industry is looked in detail there is a good demand balance. For instance, the transport sector (i.e., outsourced transport) can reach a better utilization of containers by serving industry sectors that are imbalanced, while an imbalance in the renting of construction or demolishing sector is very difficult to address if the sector handles its own containers. Thus, it is important to incorporate the information about the industry sector of the company doing the transport to develop the payload and empty container models. Table 2 shows the top ten sectors with the highest sample size in empty container data. The entire dataset comprises 159 industry sectors where, the sectors shown in the table belong to nearly 83% of the sample. Industry sector “freight transport by road” (SNI 49410) contributes to 53% of the sample, followed by “site preparation” (SNI 43120) which constitutes to 14%. Table 2 also shows that both, the share of empty containers and the distribution of empty container weights vary significantly across industry sectors. The containers weighing 2 tons or 2.5 tons are mostly the 20-ft while the 4 ton containers could be 40-ft containers. The sector with the highest share of empty containers (SNI 43991) has one

of the least shares of 40-ft containers (~13%). SNI 49410 has the highest share of 40-ft empty container movements (~40%). Hence, the industry sector (categorical) is one of the potential independent variables to include in the payload and the empty trip models.

Table 2: Data Description for Loaded and Empty Container Road Transport

SNI	Description	Obs.	Empty	%	Empty Weight		
					2 ton	2.5 ton	4 ton
49410	Freight transport by road	15 421	5 600	36%	23%	38%	39%
43120	Site preparation	4 192	1 796	43%	38%	42%	20%
38110	Collection of non-hazardous waste	1 283	309	24%	38%	37%	26%
52290	Other transportation support activities	695	287	41%	34%	38%	28%
43991	Renting of construction or demolition equipment	411	209	51%	35%	52%	13%
77320	Renting/leasing of construction machinery	573	184	32%	51%	40%	10%
41200	Construction, residential/non-residential buildings	346	152	44%	45%	47%	8%
43999	Other specialised construction activities	440	151	34%	36%	50%	14%
38320	Recovery of sorted materials	379	134	35%	39%	38%	23%
8120	Operation of gravel and sand pits; mining clays	282	124	44%	37%	30%	33%

Figure 9 shows the distribution of loaded container weights and the respective payloads in kilograms. The mean payload is nearly 17.5 tons with a standard deviation of 10.7 tons, minimum is one ton, and maximum is 78.5 tons. The payload distribution could be approximated as normal distribution based on Shapiro-Wilk test results ( $p$ -value $<0.005$ ). Hence, a linear regression model could be used to estimate the payload.

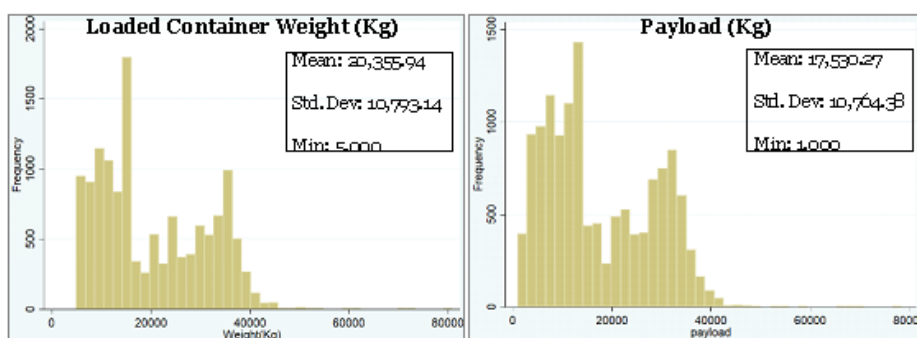


Figure 9: Loaded Container Weight and Payload Distribution

## 4.5 Empty Container Data

The truck dataset for four years (2016-2019) has a sample size of 250,000 with around 29,000 observations (~12%) belong to container truck flows i.e., 6,000 to 8,000

observations each year. Table 3 shows the number of vehicle trips and vehicle kilometers travelled by container trucks inside Sweden. The share of empty trucks varies between 44-46% for number of vehicle trips and 30-35% for vehicle kilometers. Year 2018 has the highest share of empty trips in both, vehicle trips and vehicle kilometers. On average a truck with loaded container (~95 km) travelled longer distance than that of empty container (~53 km), which shows that the trucks are often rerouted to reduce empty trip distances.

Table 3: Data Description for Loaded and Empty Container Road Transport

<b>Number of Vehicle Trips</b>				
<b>Year</b>	<b>Empty</b>	<b>Loaded</b>	<b>Total</b>	<b>% Empty</b>
<b>2016</b>	3 013	3 796	6 809	44,25%
<b>2017</b>	3 319	3 923	7 242	45,83%
<b>2018</b>	3 721	4 304	8 025	46,37%
<b>2019</b>	3 221	3 938	7 159	44,99%
<b>Total</b>	13 274	15 961	29 235	45,40%
<b>Vehicle Kilometers</b>				
<b>2016</b>	170 854	394 564	565 418	30,22%
<b>2017</b>	175 582	386 079	561 661	31,26%
<b>2018</b>	192 454	362 279	554 733	34,69%
<b>2019</b>	166 982	376 955	543 937	30,70%
<b>Total</b>	705 872	1 519 877	2 225 749	31,71%

The empty container trips are analyzed across the OD pairs at county level. About 77% of total trips belong to intra county i.e., inside the same county. The container trips within Västra Götaland, Skåne, and Stockholm counties contribute to 37% of the sample. Table 4 shows the share of empty truck container trips between the 21 country OD pairs. About 36% of OD pairs have larger than 40% empty trips (highlighted) and about 33% have less than 10% empty trips. The Analysis of Variance (ANOVA) test resulted in the within group variation with p-value less than 10%, shows that the empty container share among the counties vary significantly among the counties. The table shows there are a few OD pairs dominating the empty container movements. For instance, over 90% of containers transported from Blekinge to Gävleborgs are empty. This table provides a basis to identify the critical OD pairs with the inevitable mismatch between supply and demand, which is the key root cause of empty container movements. Also, the ideal locations for future manufacturing units (freight generators) to minimize the empty container transport could also be evaluated using the below table.

Table 4: Share (Fraction) of Empty Truck Container Trips between OD Counties

OD County	Stockholms	Uppsala	Södermanlands	Östergötlands	Jönköpings	Kronobergs	Kalmar	Gotlands	Blekinge	Skåne	Hallands	Västra Götalands	Värmlands	Örebro	Västmanlands	Dalarnas	Gävleborgs	Västernorrlands	Jämtlands	Västerbottens	Norrbottens	
Stockholms	0,5	0,6	0,6	0,3	0,2	1,0	0,2		0,0	0,5	0,0	0,3	0,3	0,6	0,4	0,3	0,6	0,0	0,5	0,0	0,0	
Uppsala	0,5	0,5	0,3	1,0				0,0		0,0		0,3	0,3	0,5	0,6	0,2	0,4	0,7	0,5		0,0	
Södermanlands	0,4	0,8	0,5	0,5	0,2		0,0			0,5	0,0	0,2	0,2	0,2	0,3	0,0	0,7	0,0	1,0		0,0	
Östergötlands	0,1	0,4	0,3	0,5	0,3	0,2	0,6		1,0	0,3	0,2	0,3	0,3	0,1	0,2	0,2	0,4	0,0		0,0	0,0	
Jönköpings	0,0		0,5	0,1	0,5	0,4	0,5	0,3	0,7	0,1	0,2	0,5	0,0	0,0	0,2	0,0	0,5	0,0	1,0	0,0	0,0	
Kronobergs	0,0			0,0	0,3	0,5	0,6		0,4	0,5	0,3	0,3	1,0	0,0	0,0		0,0		0,0			
Kalmar	0,5	1,0		0,4	0,2	0,3	0,5		0,2	0,4	0,2	0,5		0,0	0,5							
Gotlands	0,0				0,0	0,0	0,0	0,5			0,0	0,0										
Blekinge	0,3			0,0	0,3	0,4	0,5		0,5	0,5	0,0	0,1	0,0				0,9			0,0		
Skåne	0,2	0,0	0,0	0,1	0,2	0,4	0,1		0,5	0,5	0,4	0,4	0,2	0,0	0,0	0,0	0,0	0,0		0,0		
Hallands	0,5	0,0		0,0	0,7	0,4	0,5	0,5	0,9	0,5	0,5	0,5	0,0	0,5	0,0	0,0				0,7		
Västra Götalands	0,1	0,0	0,1	0,3	0,2	0,4	0,2	0,0	0,8	0,4	0,4	0,5	0,4	0,1	0,1	0,1	0,3	0,0	0,0			
Värmlands	0,1	0,3	0,5	0,1	0,3	0,0	0,0			0,0	0,0	0,4	0,5	0,3	0,2	0,6	1,0	0,3	0,0		0,0	
Örebro	0,0	0,3	0,7	0,2	0,2		1,0		0,0	0,2	0,1	0,4	0,5	0,5	0,2	0,4	0,5	0,0	0,0	0,3	0,0	
Västmanlands	0,4	0,5	0,8	0,4	0,8	1,0	0,0				0,0	0,8	0,3	0,6	0,5	0,3	0,2	0,0			1,0	
Dalarnas	0,3	0,3	0,7	0,0	0,5					0,0		0,3	0,2	0,2	0,4	0,5	0,4	0,0	0,0	0,0		
Gävleborgs	0,2	0,6	0,3	0,4	0,3	0,0		0,3	0,0			0,4	0,0	0,1	0,6	0,3	0,5	0,3	0,3	0,3	0,0	
Västernorrlands	0,0	0,0	0,0	0,0			0,0			0,1		0,2	0,0	0,3	0,4	1,0	0,5	0,5	0,5	0,5	0,2	0,1
Jämtlands	0,0		0,0		0,3							0,5		0,3	1,0	1,0	0,3	0,4	0,5	0,4	0,0	
Västerbottens	0,0			0,0	0,0				0,0	0,3		0,0		0,0	0,0	0,5	0,5	0,5	0,6	0,4	0,6	
Norrbottens	0,0	0,0		1,0	1,0								1,0	0,0	0,3	0,0	0,0	0,5	0,5	0,4	0,5	

Note: Highlighted cells have larger than 0.4; Empty cells indicate no trips happen between these OD pairs

## 4.6 Conclusions

In the context of this project a set of payload models and empty trips models were implemented to calculate empty containers flows based on the industry sector, the origin and the destination. These models can be used both for an explanatory purpose (understand which movements are more likely to lead to empty container movements) and predictive (given the lack of empty container movements for the whole country these models can be applied to get an estimate of those movements and the externalities they

generate). The empty-trips models developed confirmed the importance of imbalances in demand discussed in Section 4.1 to determine the magnitude of empty container flows.

The results show that the payload depends more on the industry sector compared to origin and destinations. The number of axles is a significant variable for payload, an increase in one unit leads to an increase in the payload of nearly 1.7 tons. The industry sectors with higher payloads are “Manufacture of other articles of concrete (SNI 23690)”, and “Warehousing and storage (SNI 52100)”. Whereas “Manufacture of metal structures (SNI 25110)” and “Wholesale of other machinery (SNI 46699)” have the least. The sectors with lower payloads most probably lead to containers being cubed out before weighing out, due to the shape of the cargo e.g., machinery, and metal structures. The year 2018 has slightly lower payloads compared to other years. Destination county plays a key role in explaining payload variability, as 17 destinations (only six origins) out of 21 counties are statistically significant. Trips either originating from “Jönköpings” and “Kalmar” or destined to “Blekinge” and “Norrbottens” have higher payloads.

The empty trips are more dependent on the OD specifically, the destination counties than the industry sector. Twelve origin counties are significant with all coefficients being negative i.e., the probability of truck container trips originating from these counties have a lesser probability of being empty than the base county. The origin county with the highest elasticity of -0.15 is “Kalmar”, which implies that if a trip originates from “Kalmar” the probability of the container truck being empty decreases by 15%. Other origin counties with higher elasticities (values in parenthesis) are: Kronobergs (-0.14), Västra Götalands (-0.13), and Blekinge (-0.13). Among the destinations, the top five counties with the highest elasticities (values in parenthesis) are: Blekinge (0.39), Västra Götalands (0.38), Skåne (0.37), Kalmar (0.37), and Jämtlands (0.35). There are four counties (Blekinge, Västra Götalands, Skåne, Kalmar) common as both, origin, and destination among the top five counties with larger elasticities. For instance, the county “Västra Götalands” has more probability of having an empty trip as a destination but as an origin the same county has one of the lowest probabilities to have an empty trip. It is noteworthy to notice that all these four counties have major ports in Sweden with more imports than exports. The industry sector with the highest probability of having an empty container trip is “Trade of electricity (SNI 35140)” with elasticity of 0.62; followed by “Manufacture of other articles of concrete (SNI 23690)” with elasticity of 0.47.

The key recommendations with respect to future data collection for empty container modeling include, i) for the road goods transport data: include the type of container (20 ft and 40 ft), OD pairs at municipality level. ii) CFS data: differentiate between containerized and non-containerized cargo for each mode.

The detailed models and results can be found in Kalahasthi et al (2023).

# 5 Description of strategies for analysis

This project identified different strategies for either reducing the empty container repositioning or making it more efficient within the national transport system. The strategies were identified based on interviews with multiple stakeholders.

The benefits of selected initiatives were assessed based on the savings that could be obtained from them. These initiatives include:

- (1) transporting loaded and empty containers from/to the sea ports via inland terminals using rail instead of using direct trucking
- (2) foster reutilization of containers by
  - a) matching import and export containers with direct truck transport from/to seaport (also called street turns)
  - b) matching import and export containers with direct truck transport via inland terminal (also called street turns)
  - c) matching import and export containers allowing storage of the container at the inland terminal
- (3) triangulation between inland terminals.

## 5.1 Using rail transport to/from seaports – dry ports

The first initiative concerns use of rail instead of truck for transport to and from a seaport. 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, with electrified rail the CO<sub>2</sub> 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, 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 *et al.*, 2020). Services at dry ports vary from the basic, including transshipment and the storage of containers, to the more customer-specific, including sorting and kitting (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 empty containers, or what are called “dry port depots” (Roso *et al.*, 2009).

The upper illustration in Figure 10 shows how trucks may transport loaded containers and position empty containers between seaport and companies importing and exporting cargo. In the lower illustration a rail connection between seaport and dryport results in shorter distance travelled by truck. Dry ports can facilitate emissions reductions per kilometer and lower costs due to the movement of empty containers by rail. It also offers the availability of storage space close to customers, and, often, a unique transport operator that can coordinate operation to minimize empty container movements. Although some of those opportunities with dry ports have already materialized, their effects have yet to be quantified.

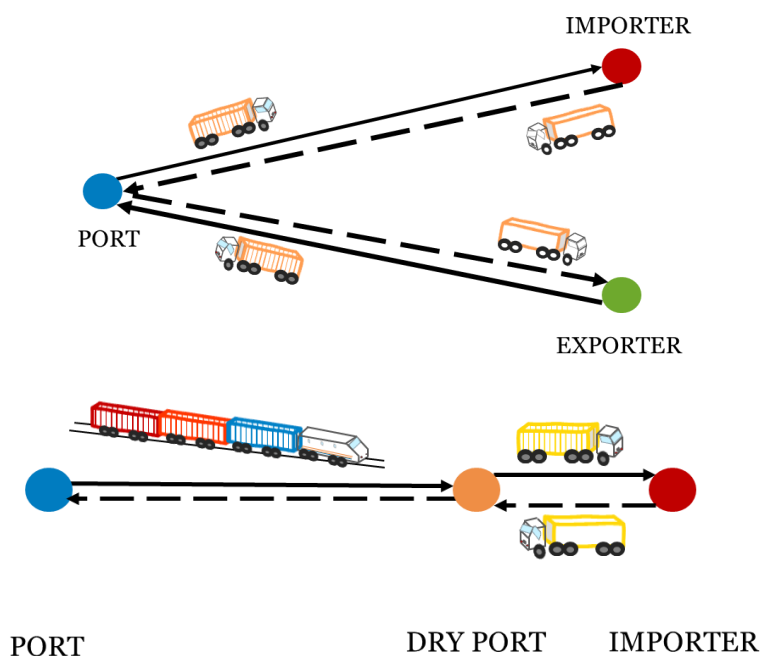


Figure 10: Illustration of rail transport between seaport and a dry port compared to truck transport

## 5.2 Reutilization of containers

In theory, containers used for import might be reutilized for export. One of the main problems when optimizing the use of empty containers inland is the asymmetry of demand. In Sweden, this imbalance is not so obvious when looking at the total number of export and import operations (e.g., the data studied for all operations handled by a large port in Sweden showed 51% import containers, and 49% export containers. However, a match is needed in terms of (i) space, (ii) time, and (iii) ownership of the container.

Spatially, the demand balance needs to be studied by geographical area. Geographical areas with a good demand balance tend to offer a better opportunity for reutilizing a stripped import container for an export operation. The time dimension depends on the

seasonality of operations and the volume of operations. Basically, if there is a high volume and imports and exports happen simultaneously, it is more likely that an export operation can happen within “the free temporary storage” time following an import operation, and thus reutilization can be achieved. Further, the ownership of the container by shipping lines plays an important role in utilization because containers are not interchangeable across shipping lines. In essence, if demand from an area or an inland terminal is served by fewer shipping lines it is more likely that containers can be reutilized.

When an emptied container can be reutilized immediately for export cargo, this is called a street turn. This is further described in 5.2.1. Transport operators and forwarders play an important role in identifying opportunities for reutilization in terms of matching emptied import containers with cargo for export. One way to foster reutilization of containers is to give more time to transport operators and freight forwarders to find an export customer for an empty container. This strategy is referred to as extended storage at inland terminals and described in 5.2.2.

### 5.2.1 Street turns

A *street turn* is an operational strategy that shortens the distance traveled. Instead of returning an import container stripped at a consignee or importer to a port terminal, the empty container is directly transported to a shipper or exporter, stuffed with export cargo there, and subsequently transported to a port. A street turn can either be direct truck transport from/to the seaport (Figure 11) or go via an inland terminal (Figure 12). In the first situation a positioning trip of an empty container between importer and exporter replaces two empty container movements, (1) from the importer to the seaport/depot and (2) from the seaport/depot to the exporter. In the latter situation it replaces empty container movements (1) from the importer to the terminal and (2) from the terminal to the exporter. 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.

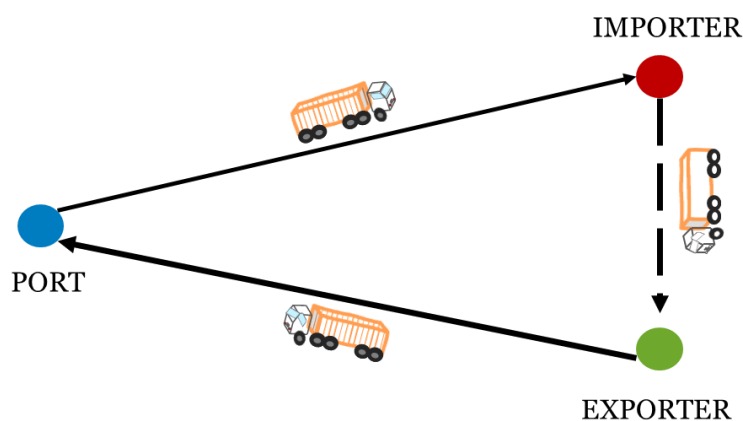


Figure 11: Matching import and export containers with direct truck transport (street turn)

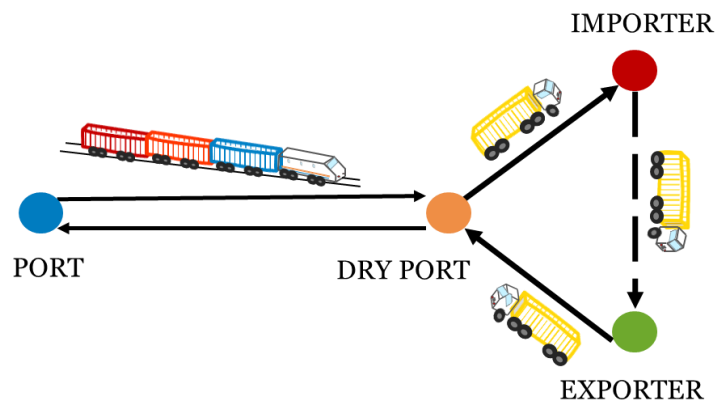


Figure 12: The street turn via a dry port

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).

Earlier studies have mainly approached street turns from the shipping line perspective (Jula *et al.*, 2006; Deidda *et al.*, 2008; Furió *et al.*, 2013). More recently, Legros *et al.* (2016; 2019) considered the perspective of the consignee. Two of the master theses connected to the project found that transport operators and freight forwarders played a key role in operationalizing street turns (Hellekant *et al.*, 2021; Karlander *et al.*, 2021). Collaboration-oriented initiatives, wherein transport operators exchange empty containers with each other to increase street turns, have also been described (Sterzik, 2013; Caballini *et al.*, 2016).

## 5.2.2 Extended storage at inland terminals to allow matching

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 *et al.*, 2019). Inland terminals or dry ports can serve as such locations by temporarily storing empty containers (Figure 13) when a direct street turn is not possible. For example, Bergqvist *et al.* (2021) have described how the Falköping terminal in Sweden acts as an empty container depot for the region's customers. In such cases, when transport demand arises, an empty container can be transported a shorter distance to the consignor, filled, sent back to the dry port, and transported to the seaport by rail when the intended vessel's estimated time of arrival approaches. For ECR, the use of dry ports for empty container storage is beneficial because the shorter distances that it creates (Hagelin *et al.*, 2020; Hellekant *et al.*, 2021) reductions in transport costs, 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 *et al.*, 2019).

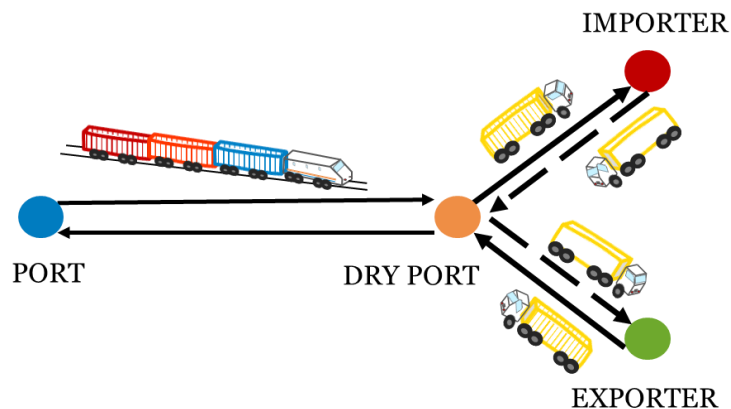


Figure 13: Extended free temporary storage at a dry port

The literature also underscores the importance of the empty container storage location. High trade volumes are important for businesses (Boile *et al.*, 2008), and their imbalance may result in a surplus or deficit of empty containers 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). Costs stemming from container storage at dry port depots (Hagelin *et al.*, 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 empty containers closer to the port area and to minimize the total number of storage locations (Boile *et al.*, 2008; Hellekant *et al.*, 2021). However, storage costs at dry ports, as inland locations, are usually lower than at port terminals (Roso *et al.*, 2009), which can be a benefit for shipping lines. Furthermore, positioning empty containers at such locations can increase the catchment area of transport demand (Bergqvist *et al.*, 2021).

A concern 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 *et al.*, 2019). Thus, after unloading, importers seek to send empty containers 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 empty containers back to the seaports when they are returned from importers. However, if additional free time to store empty containers is allowed, e.g. in the dry port, then the possibility of finding a matching export demand increases, and redundant empty container movements can be avoided.

### 5.3 Triangulation between terminals

In cases where a reutilization is not possible in the area surrounding a dry port due to local imbalances, low volumes and ownership, it is still possible to avoid a backhaul, i.e.,

return of empty containers to the port. This is possible with a triangulation strategy that enlarges the scope so that containers that were used for an import operation at one inland terminal are sent to a different terminal to be used for an export operation. The potential for implementing triangulation between two inland terminals depend on (i) the triangle distance factor, i.e., how far away the two inland terminals are located from each other compared to the distance to the port, and (ii) the imbalance ratio between inland terminals, balancing demand by matching high export zones with high import zones into a triangle. The main criterion to determine if a triangle is feasible is the total container kilometers saved which can easily be converted into energy savings. One additional important criterion is the collaboration between the two terminals as the process needs effective, on-time and continuous information sharing.

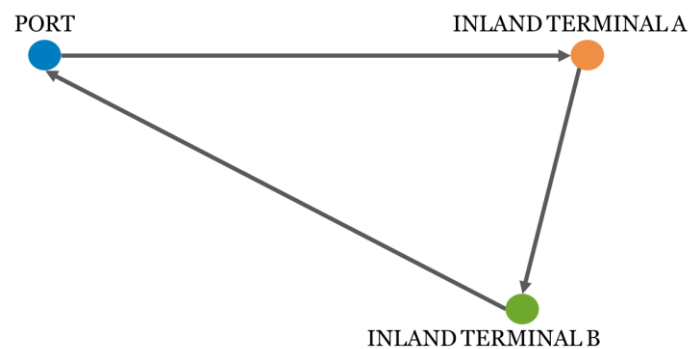


Figure 14: Triangulation between terminals in different parts of the country

# 6 Quantitative assessments of strategies

Following the investigation of different ECR strategies, several of them were selected to analyze further and estimate their improvement potential. Real life cases and actual transportation data are required to achieve such an objective. Hence, several cases that include the above-mentioned actors were selected and contacted. Actual transport data over a selected duration were collected and the ECR strategies were simulated over this data to calculate the improvement potential in terms of cost and emissions. For further reading, see Castrellon et al. (2023).

## 6.1 Reducing ECR locally: Case Eskilstuna

The intermodal operation between Eskilstuna dry port and the Port of Gothenburg (Figure 15) was selected as a case study to assess environmental and economic benefits of strategies to reduce ECR. A computer simulation was trained with real data of container movements from import and export operations between 2019 and 2021. The base case (current situation) performance, i.e., kilometres-travelled, cost and CO2 emissions, was compared to the performance of two hypothetical ECR reduction strategies, namely, street turns and extended free temporary storage (FTDP), under three different collaboration levels of owner container substitution.

<i>NO COLLABORATION:</i>	Shipping lines run their own ECR operations, reluctant to share containers.
<i>ALLIANCE COLLABORATION:</i>	Ownership container substitution possible within commercial alliances between shipping lines, i.e., 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 constituted all 12 remaining companies not in any alliance.
<i>FULL COLLABORATION:</i>	Shipping lines collaborate so that container substitution is always possible for shippers, meaning that container swapping, borrowing, or interchange was enabled with no distinction of container brand.

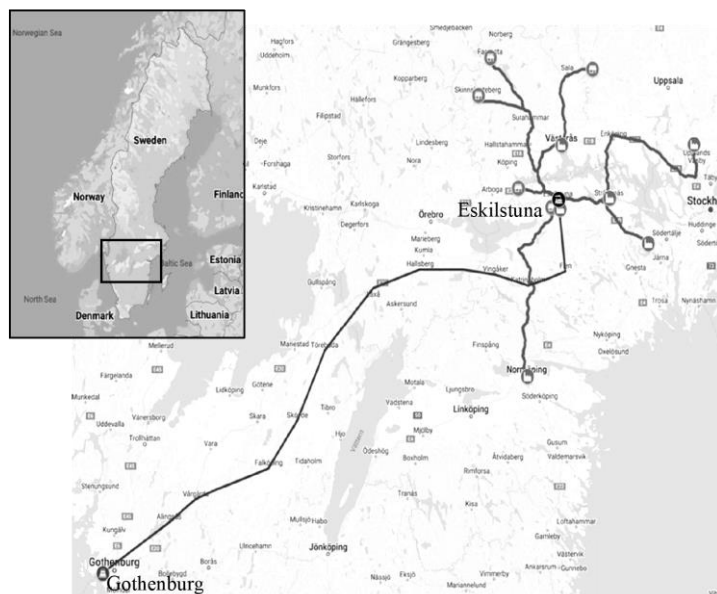


Figure 15: Geographic scope of the case study

The simulation model encompassed seven experimental configurations, each one representing a different combination of ECR strategies with incremental features:

- |              |    |   |   |
|--------------|----|---|---|
| Base case    | i. | Base case: inland network with dry port |   |
| Street turns | {  | ii.                                     | Inland network with street turns via dry port with no collaboration   |
|              |    | ii.                                     | Inland network with street turns via dry port with alliance collaboration   |
|              |    | iv.                                     | Inland network with street turns via dry port with full collaboration   |
| FTDP         | {  | v.                                      | Inland network with street turns via dry port and additional match-backs enabled by extended free temporary storage with no collaboration       |
|              |    | vi.                                     | Inland network with street turns via dry port and additional match-backs enabled by extended free temporary storage with alliance collaboration |
|              |    | ii.                                     | Inland network with street turns via dry port and additional match-backs enabled by extended free temporary storage with full collaboration     |

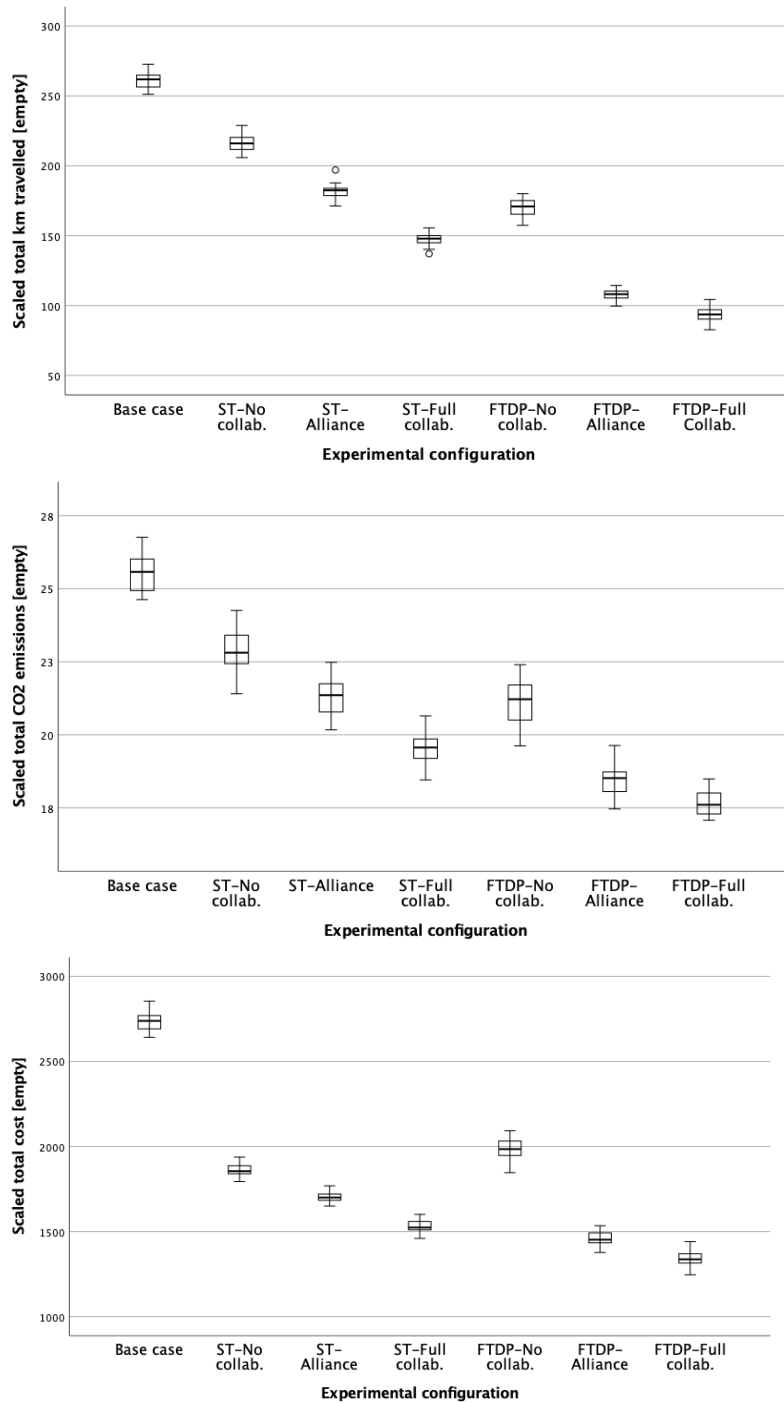


Figure 16: ECR km-travelled (top), CO2 emissions (middle) and cost (bottom)

In the simulation results (Figure 16), direct street turns were found to have a positive impact on reducing ECR costs, particularly when combined with collaboration-intensive scenarios involving container ownership substitution. For example, compared to the base case, the total cost reduction attributed to street turns ranged from 7% to 10% for the entire system (empty + laden containers), assuming no collaboration between container owners. This reduction was achieved by matching 26.83% of export containers with prior import container operations. The corresponding reduction in CO2 emissions did not exceed 6%. However, when full collaboration among container owners was possible, matching of import and export container operations reached 67.55% of export containers, and the cost savings and emission reductions were twice as big as street-turns under the scenario of no collaboration.

The extended storage scenario outperformed street-turns, leading to nearly double the eco-efficiency benefits. For instance, considering ECR alone, reductions in environmental impacts reached up to 32% under full collaboration with ownership container substitution. The availability of extended storage options at the dry port significantly increased the likelihood of finding match-back opportunities. By allowing empty containers to remain at the dry port until a suitable export match is identified, the storage time played a crucial role in facilitating match-backs. However, this arrangement may require negotiations among freight forwarders, dry port operators, and shipping lines concerning drop-off timing, location, as well as storage and demurrage costs associated with empty containers.

The sensibility analysis in Figure 17 shows 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 (best performer). Under the scenario of no collaboration, match-backs occurred for 54% of the export containers. Since the limit of ten days of storage maintained a positive balance between ECR savings and storage costs, impacts of extended free temporary storage were computed using ten days as a storage time parameter.

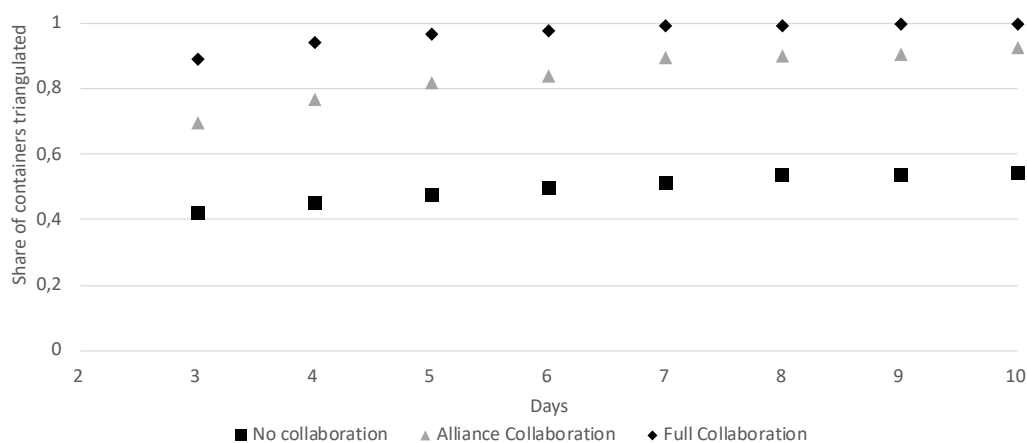


Figure 17: Sensibility analysis of free days for dropping off empty containers

While shipping lines' collaboration was shown to significantly reduce environmental impact, there are implementation challenges to realize the suggested improvements. For instance, 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 (Hagelin *et al.*, 2020). Nonetheless, collaboration within existent commercial alliances could be the platform for a first step toward container substitution under full collaboration scenarios.

The extension of free temporary storage at a dry port could reduce importers' incentives to return empty containers as quickly as possible, generating the need of more containers in the system. Also, 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, or increased profit due to increased container volumes from new customers (Bergqvist *et al.*, 2021). Therefore, each case should be assessed individually and in a holistic way to create system-level efficiency and reduce externalities.

Further implementations in other contexts should also consider that results from this case correspond to 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. Export-dominated regions could face different challenges and therefore results

may vary. Also, implementation outputs will highly depend on other contextual conditions such as 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.

Methodological details about this case study are available in Castrellon et al. (2023).

## 6.2 Implementing ECR at the regional level

A case study was conducted of the container movements between a Swedish seaport and its connected inland terminals to explore if potential for reducing ECR existed. Drawing on the data, both opportunities for reutilization in the area surrounding each inland terminal were examined as well as opportunities for triangulation between inland terminals. The first research question concerned if there were container flows that could be reutilized or triangulated. In a second step it was examined how container flows with high relevance for triangulation could be identified, i.e. what factors could help identify triangles with high potential to reduce ECR. This latter step can help stakeholders decide which triangles could be interesting.

### 6.2.1 Reutilization

Using data of the current container movements between a seaport and its connected inland terminals, it was apparent that reuse where emptied import containers were immediately used for export cargo was very rare. The potential for such reuse was simulated considering the demand for export container the same date as import containers were delivered to an inland terminal.

The study also calculated asymmetry between import and export for 11 inland terminals, showing that 5 terminals were import-dominated, and 6 were export dominated. Of these, four terminals had almost only export flows while the others had a varying degree of flows in both directions. Terminals that have more import than export operations and have a high dominance of one or few shipping lines had the highest potential for reutilization. The savings on energy and emissions of reutilization depend on the distance from the terminal to the port.

The highest potential for reutilization of containers in the areas surrounding specific inland terminals was around 50% in terms of quantity. For four terminals the potential was 53%, 49%, 48% and 42% respectively. Only considering reutilization in just one of these terminals constitutes a saving of 700 000 container-km, 212 000 kWh, and 2390 kg CO<sub>2e</sub> emissions. For another group of terminals, the potential for reutilization was low, ranging between 0-5%. Thus, the findings show that for the terminals with the right profile reutilization is worth considering.

### 6.2.2 Triangulation between inland terminals

The potential for triangulation between inland terminals so that emptied import containers at one inland terminal could satisfy the demand for containers for export cargo at a different terminal was explored in a simulation drawing on current container movements between a Swedish seaport and connected inland terminals.

The base case modelled the current situation, where containers arrive at the seaport, these are then transported by rail to inland terminals and from there sent to importers by truck. Meanwhile, containers loaded with export cargo are collected from exporters and transported by truck to inland terminals and from there to the seaport by rail. In the current network, each inland terminal has a separate connection to the seaport where containers are transported between each inland terminal and the seaport. This means that emptied import containers may be returned to the seaport, while the demand in other inland terminals for empty containers is satisfied from the seaport. In fact, as outlined in Table 5, movement of empty containers is 50% of total container-kms in the base case. Movement of containers between inland terminals, i.e. triangulation, does not occur by rail (even if a rail network exists). Therefore, potential triangulation between inland terminals was simulated using the different collaboration levels described in 6.1.

- i. Base case: container movements between seaport and inland terminals
- ii. Triangulation between inland terminals with no collaboration
- iii. Triangulation between inland terminals with alliance collaboration
- iv. Triangulation between inland terminals with full collaboration

In the simulation, it was first checked if the emptied import container could be re-utilized within the hinterland of the same inland terminal. Secondly, if reuse was not possible locally, it was checked if it could be re-utilized at other inland terminals, i.e. satisfy the demand for export containers at other inland terminals. If neither of these reutilization strategies were possible, the containers were returned straight to the seaport. Also, if the demand for export containers could not be fulfilled by containers from other terminals, it was supplemented by empty containers from the seaport.

The findings indeed indicate potential for reduced ECR by triangulation between Swedish inland terminals. Triangles were first identified and evaluated considering a network optimum with reutilization and all possible triangulations between terminals. Table 5 outlines how the distance was reduced in the various configurations.

Table 5: Number of container-kilometers in the network optimum

<i>Configuration</i>	Empty Import	Empty Export	Total Empty	Incl. Laden containers
	(million container-km)			
Base Case	7,03	10,5	17,53	35,06
No Collaboration	4,53	8,39	12,92	30,45
Alliance Collaboration	3,71	7,6	11,31	28,84
Complete Collaboration	2,5	6,35	8,85	26,38

Kilometers driven is an important performance measure. Results show that the kilometers transporting empty containers is reduced by 26% in the ‘No collaboration’ configuration, by 35% in the ‘Alliance Collaboration’ configuration, and by 50% in the ‘Complete collaboration’ configuration, compared to the base case. Another important performance measure is the number of containers needed to satisfy the demand for empty containers for export. In the network optimization, the number of the unique containers needed reduced significantly. Figure 18 illustrates that while in the base case all containers were supplied from the seaport, this number decreased to 62%, 49% and 33% of the containers respectively in each configuration. Instead, a large share could be

reutilized and another large share triangulated. Thus, in the ‘No collaboration’ configuration, where shipping lines do not share containers, as is the case today, the study shows that 18% of the demand for export containers in inland terminals could be satisfied by transporting them from another inland terminal and the distance of repositioning empty containers reduced from approximately 17.5 to 13 million container-km. The energy and emissions savings are low due to the use of rail, providing 3%, 4%, and 6% saving in respective configuration.

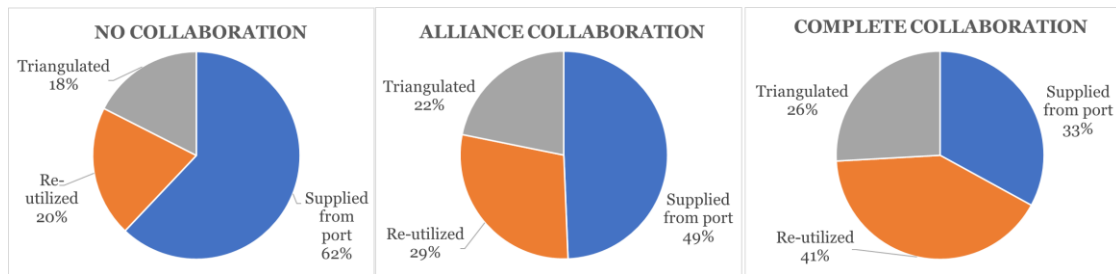


Figure 18: Source of empty containers

In the network optimum, triangulation is performed as much as possible. In practice, only some of the triangulations may be realised. Therefore, the study also looked at how the most promising triangles could be identified and evaluated in isolation, when only certain flows were realised. At this point only ‘No collaboration’ between shipping lines was studied, as this is the situation presently, and therefore most relevant for discussion regarding implementation.

One performance metric that could help decisions is the total number of containers in triangulation flows. Another could be the total container-kms, energy and emission savings for each triangle. Testing the data set for each of these two performance metrics resulted in different triangles. Considering the number of containers when identifying the most interesting triangles, around 1000 containers were triangulated in each of the three most interesting triangles. Figure 19 illustrates that the number of containers supplied from the seaport in the top three interesting triangles based on the number of containers was 46%, 66% and 67% respectively, which can be compared to the 62% in the network optimum (Figure 18). Triangulation potential is a bit lower compared to the network optimum, but still 23%, 13% and 12% in respective triangle. If instead considering the maximum savings in distance travelled only one of the triangles identified when considering the number of containers makes it into the top three most interesting triangles. The triangles with most potential for reducing distance had the potential to reduce container-kms with around 1000 000 container-kms each (1251, 1174 and 996 thousand kms respectively). This represents savings between 31 and 55%.

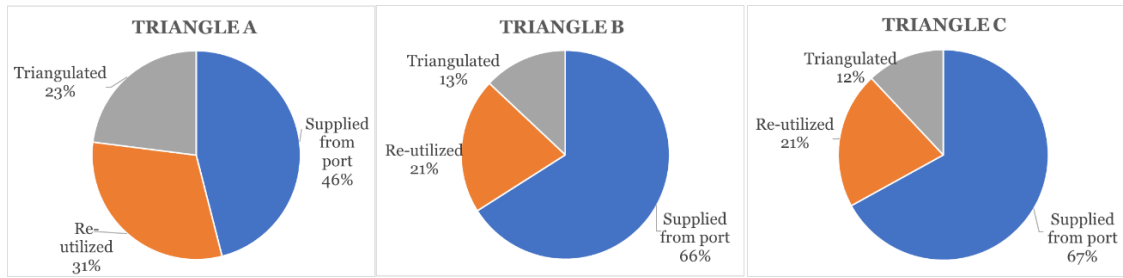


Figure 19: Source of empty containers in top triangles based on the number of containers

Further, the share of containers for each shipping line in each triangle could help identify which shipping lines that might be interested in triangulation. Looking at the share of containers transported within each triangle, the flow of three shipping lines were identified as most interesting, as they represented a large share of the container flows to several inland terminals. In addition, two further shipping lines have significant flows to specific inland terminals that might be worth looking into. Also, analysis of seasonality is important for making decisions, where for example quantities in a specific terminal may vary over the year, meaning that triangulated empty container flows are not stable.

The results need to be considered in light of the assumptions and limitations in the study. One major assumption was that all containers were considered to be of the same size (40ft). Considering that there are various types, this could lower the potential for re-utilization regionally as well as locally. Another assumption concerns the time needed, where containers were emptied and refilled the same day. In practice, more time may be needed for stripping the container at an importer and stuffing it at an exporter. Another constraint, that could reduce the practicality of triangulation, concerns that rail wagons are needed for loading the containers on rail. These thus would also need to be triangulated. The ownership of this equipment would need further investigation.

# 7 Stakeholder perspectives on scenarios to reduce empty container repositioning

Considering the multiple stakeholder structure of the ECR process, understanding how the different scenarios were perceived by the different actors involved in the inland ECR transportation chain was needed. A Multi-Actor-Multi-Criteria-Analysis (MAMCA) was conducted to evaluate three scenarios of opportunities to reduce empty container repositioning in the hinterland of a port. MAMCA is a tool that allows various stakeholder perspectives to be included in decision-making, allowing comparisons between different stakeholder perspectives on the same situation. By taking important criteria, or key performance indicators, that are important to each stakeholder into account it is possible to evaluate how attractive each scenario is and get a good understanding of advantages and disadvantages with each scenario from multiple stakeholder perspectives. MAMCA has been used in earlier studies covering a variety of topics and is for example recommended for increasing knowledge and as a basis for developing policy recommendations that can be accepted by several stakeholders. Examples of applications include evaluating logistics terminals, urban deliveries, different biofuels. An online software has been used with an established process. For more information about MAMCA, see [www.mamca.be](http://www.mamca.be). Following the use of the online tool, visual graphs were created in Excel to display the results.

## 7.1 Stakeholders

The stakeholders included in the MAMCA were shipping companies, inland terminals, transport operators, forwarders, and shippers (i.e. importers/exporters). These had been identified as participating in the container management process, and therefore important for any implementation of improvements, such as those suggested in the three scenarios. Workshops were conducted with representatives of each stakeholder group. When it was difficult to gather participants at the same time, multiple workshops were conducted for those stakeholder groups. Table 6 below lists the workshops conducted and how many participated in each workshop.

Table 6: Participants in MAMCA

	Participants	Date
Inland terminals	2	Nov 2022
Transport operators	3	Nov 2022
Shipping companies	4 (2 per workshop)	Nov-Dec 2022
Forwarders	2	Dec 2022
Ports	2	Apr 2023
Shippers	3 (1 per workshop)	Apr-May 2023

## 7.2 Criteria

Important criteria for each stakeholder group were identified. At each workshop important criteria were agreed and then prioritized. A list of criteria had been prepared for each workshop and it was possible to add or remove criteria during each workshop. Four criteria groups were used for all stakeholder groups: criteria related to Finance, Sustainability, Efficiency and Delivery service. Within these the individual criteria differed depending on the stakeholder group. For sustainability the criteria only differed slightly. Table 7 shows the criteria listed at the workshops. These criteria were of general importance to each stakeholder, e.g. income, but also included more specific detailed components of relevance for container management.

Once the important criteria had been agreed, the next step in the workshop was to prioritize the criteria. This was done with a 100 scale relative comparison, where the criteria groups first were compared and the participants asked to rate the most important as 100, and thereafter relate the importance of the remaining criteria to that on a scale from 0-100. When the criteria group had been prioritized the same exercise was conducted comparing criteria within each criteria group and assigning importance of 0-100. At this point the participants had not yet been asked about any scenarios, thus the prioritization was general for each stakeholder. Opinions regarding priorities could differ between the participants in each workshop and discussions were used to reach a common reply.

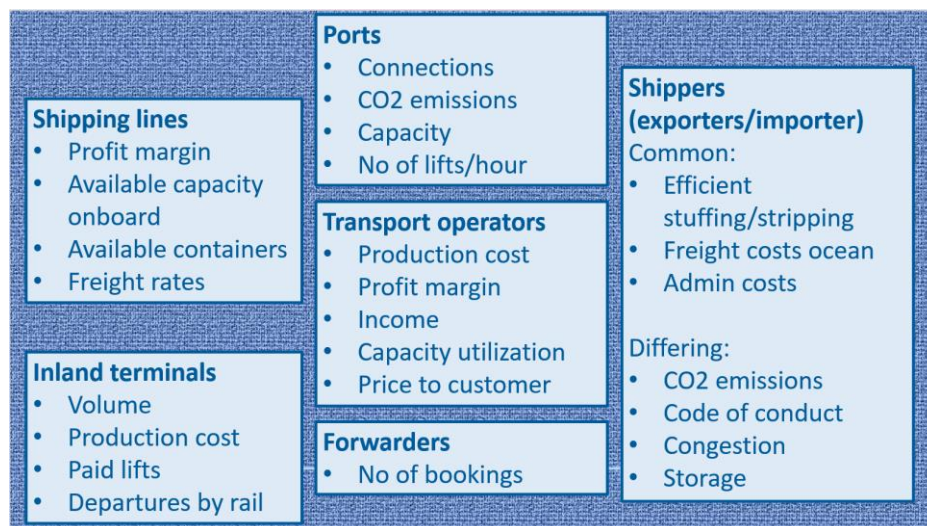


Figure 20: The most important criteria per stakeholder group

Table 7: Criteria for MAMCA stakeholders

	<b>FINANCE</b>	<b>SUSTAINABILITY</b>	<b>EFFICIENCY</b>	<b>DELIVERY SERVICE</b>
Inland terminal	Production cost Volume Investments Profit margin	CO2 emissions Local emissions (nOx, sOx, Particles) Social code of conduct Noise Congestion	No. of stripped, stuffed containers/month No. of lifts/hour Surface utilisation Non profit lifts No. of paid lifts	Availability of empty containers Frequency of rail departures No. of loaded containers stored Container ready for inland transport in time Time to have container (port-terminal-port)
Transport operator	Production cost Profit margin Income Street turn fee	CO2 emissions Local emissions (nOx, sOx, Particles) Social code of conduct Congestion	Capacity utilization Share loaded Share empty Admin	Time available Delivery precision Frequency Available resources Lead time
Shipping line	Port fees (handling) Port fees (yard) Asset investment (container) Street turn fee Profit margin Income from sales (freight rates)	CO2 emissions Local emissions (nOx, sOx, Particles) Social code of conduct Noise	Time in port TEU Turn-around time (port-inland-port) Admin time No. of round trips/year Level of imbalance between import and export Capacity utilisation on vessels (payed TEUs)	Quality of container Available capacity onboard Availability of containers Service reliability
Port	Production costs Volume Investments Profit margin	CO2 emissions Local emissions (nOx, sOx, Particles) Social code of conduct Noise Congestion	No. of lifts/hour Surface utilization Non profit lifts No. of paid lifts Container dwelltime	No of connections (line + rail) incl. frequency Available capacity (no. of containers/ time) Available storage capacity for empty containers in depots No. of containers inspected
Forwarder	Prod cost Profit margin Income Street turn fees Detention cost Storage cost (depot)	CO2 emissions Local emissions (nOx, sOx, Particles) Social code of conduct Congestion	No. of bookings/employee	Delivery on time Time available Available capacity truck/rail/vessel Flexibility
Shipper	Transport cost inland Demurrage fee Detention fee Ocean freight cost Warehouse stuffing and handling cost Storage cost terminals	CO2 emissions Local emissions (nOx, sOx, Particles) Social code of conduct Noise Congestion	Efficient stuffing & stripping of container Minimise admin Minimise waiting time for drivers	Capacity guaranteed No damages Delivery reliability Delivery time (days) Advance notice Delivery precision of container

## 7.3 Scenarios

Three scenarios were evaluated in the MAMCA exercise. These scenarios were developed by the research group based on the initially identified improvement opportunities and refined with the assistance of the project reference group. The scenarios were selected to challenge stakeholders in their thinking of the current situation.

### **Time Flexibility**

The background to this scenario is that the time a container can be kept in the inland is constraining the possibilities to find matching export cargo. This means that if a container was allowed longer before being returned to a depot near the port, then it may be possible to find more matches between emptied import containers and new export cargo. Therefore, in this scenario we allow additional days to find matching export cargo. Further, it was pinpointed in interviews that the demands from importers and exporters regarding specific time slots for dropping off or picking up containers could limit possibilities to find matches between emptied import containers and new export cargo. Therefore, in this scenario we allow a flexibility regarding the timing of the drop off or pick up.

### **Container Sharing**

The background to this scenario is that matching emptied import containers with export cargo in the current situation need to use the same shipping line, as these own the containers. This scenario relaxes this constraint, considering that it would be possible to achieve more matches of import and export without restrictions regarding shipping line used. This is also explored in the quantitative study, see 6.1. This would for example work if the containers were so called grey boxes, not branded by each shipping line, or units specifically owned by each shipping lines. As interviews suggested that this was a difficult hurdle to overcome, this scenario only considered relaxing the constraint by allowing shipping lines in the same alliance to share containers. Presently they have agreements regarding slots on container vessels and this scenario was defined to explore what would happen if they could come to an agreement also regarding containers.

### **Data Sharing**

The background to this scenario is that transport operators as well as forwarders can match containers among their own customers but not with importers and exporters using another transport operator or forwarder to arrange for their cargo. Thus, an exporter located next to an importer would not be able to utilise a just emptied container from its neighbour if they use different transport operators or forwarders. This scenario, therefore, sets out to explore increased transparency regarding available containers for export in the inland that could make further matching of emptied import containers with export cargo possible.

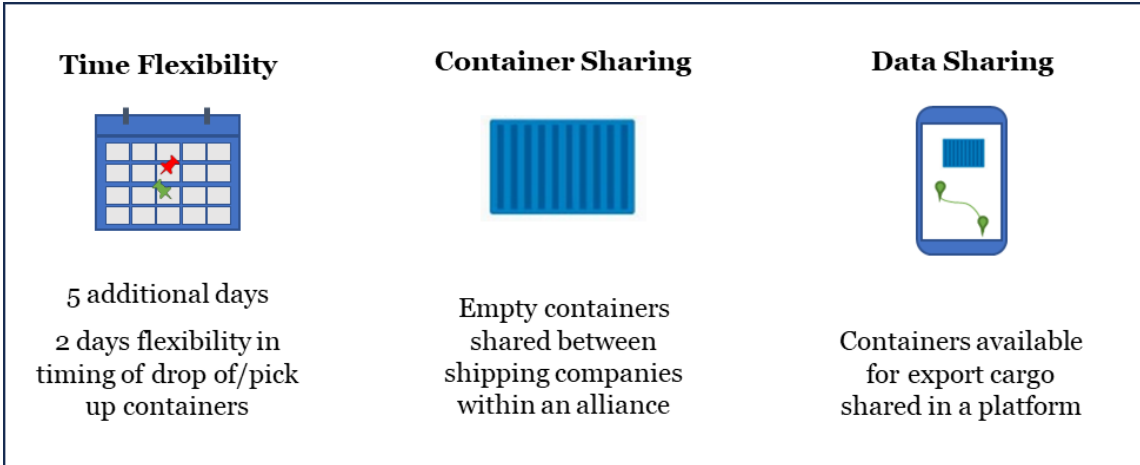


Figure 21: Overview of scenarios evaluated in the MAMCA

During the evaluation in the MAMCA tool the participants compared how the scenarios would influence each criteria compared with the present situation, on a scale from 0-10, where 0 was very negative, 5 was no change and 10 very positive.

## 7.4 Analysis and results

In the analysis first the results for each stakeholder group for the three scenarios were visualised and discussed. Thereafter, the results for multiple stakeholders were compiled. These were presented and discussed with the participants at a follow-up seminar in May 2023.

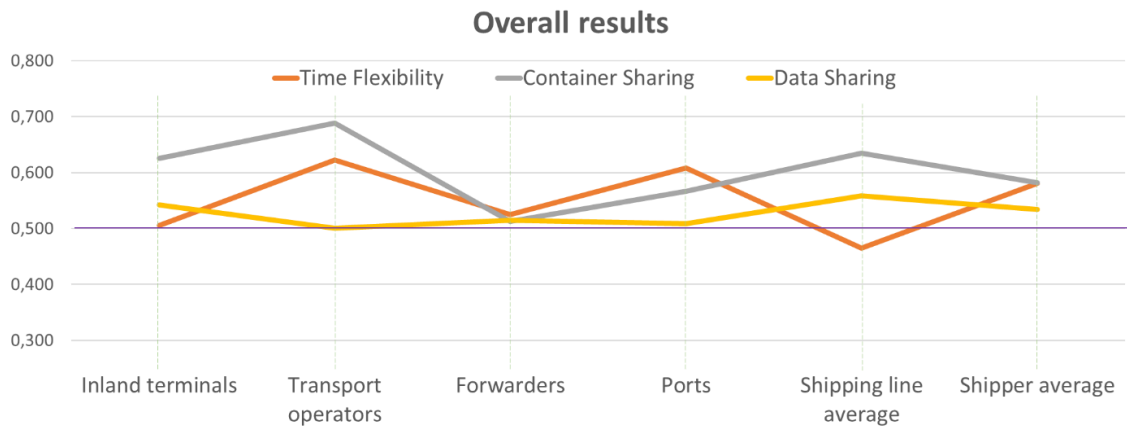


Figure 22: Overall MAMCA results

The overall result graph from the MAMCA (Figure 22) shows the three scenarios (Orange = Time Flexibility; Grey = Container Sharing; and Yellow = Data Sharing) as more positive or negative compared to the present situation (purple line indicating 0,5). As can be seen the stakeholder prefer different scenarios. Most of the scenarios have been assessed as an improvement for most of the stakeholders compared to the present

situation. The biggest exception is Time Flexibility for Shipping Lines which was evaluated as slightly negative compared to the present situation.

Transport operators were in general most positive to the scenarios, but saw little change for the Data Sharing scenario. The evaluation of Container sharing by Shipping Lines was surprisingly positive, which will be delved deeper into below under 7.4.5.

## 7.4.1 Inland Terminals

Inland terminals were most positive to the scenario Container Sharing. The Data Sharing scenario was evaluated as slightly positive. They did not see much difference between Time Flexibility scenario and the present situation.

For inland terminals volume is the most important criteria and this is evaluated as the same as the present situation for all scenarios. Container sharing is evaluated as more positive for other important criteria, including production cost, number of lifts, availability and frequency. Both the scenario of Container Sharing and Data Sharing are evaluated as positive for the number of stuffed or stripped containers in the inland terminal.

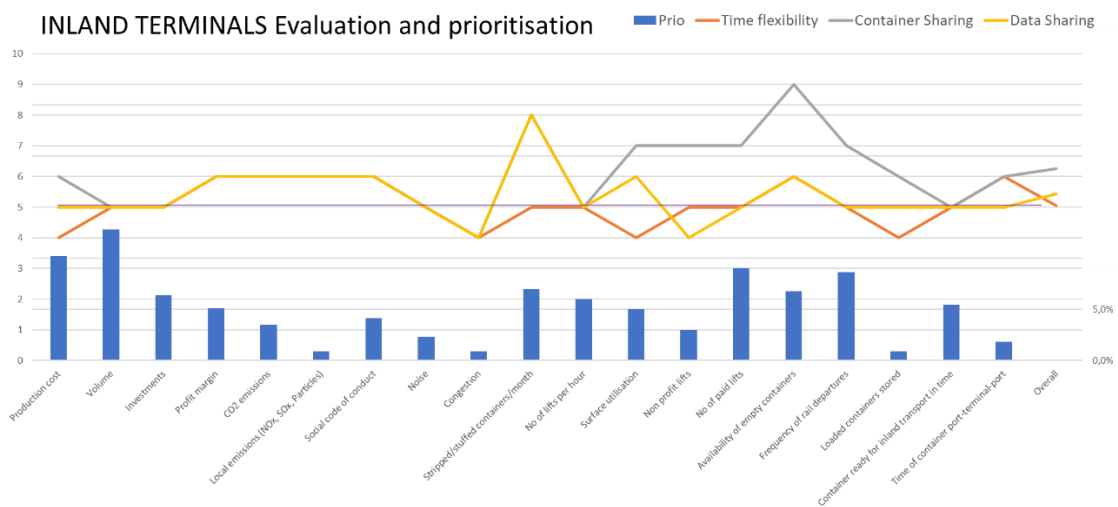


Figure 23: MAMCA for Inland terminal respondents

## 7.4.2 Transport Operators

Transport operators were positive to both Container Sharing and Time Flexibility scenario, with Container Sharing evaluated as more positive for most criteria, except street turn fee and administration. They did not see much difference between the Data Sharing scenario and the present situation.

Important criteria for the transport operators include financial (production cost, profit margin, income) and Capacity utilization, which is an efficiency measure. Container Sharing is evaluated as most positive (slightly more positive than Time Flexibility) for

several important criteria, including production cost, profit margin, capacity utilization, available time and share of loaded containers.

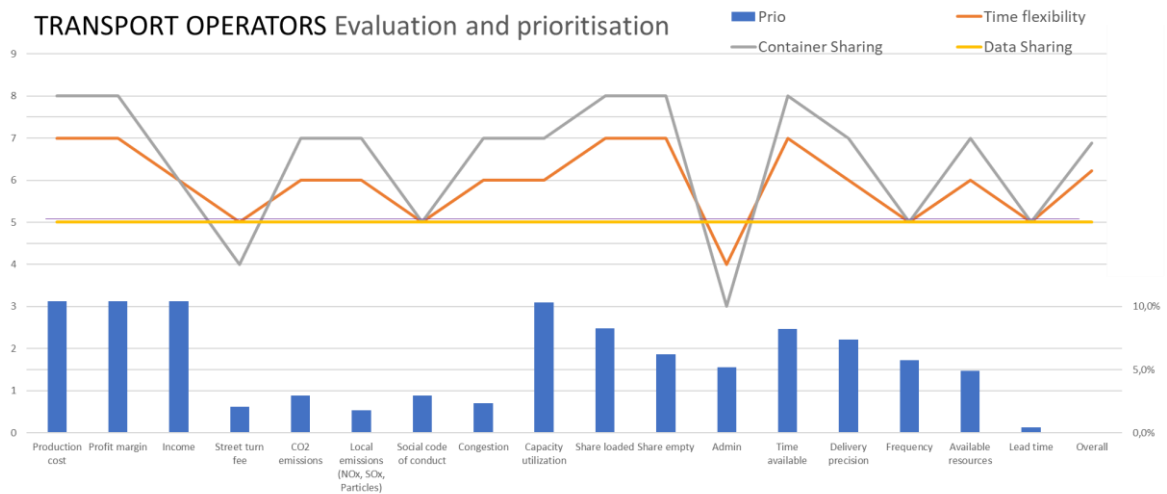


Figure 24. MAMCA for Transport operator respondents

### 7.4.3 Forwarders

Overall, the forwarders did not see much difference between the scenarios nor compared to the present situation. Digging into more detail, however, the scenarios impacted various criteria negatively or positively. Container Sharing was evaluated as positive for production cost but slightly negative for delivery precision. Time Flexibility on the other hand was evaluated as positive for detention costs, delivery precision and available time, but as slightly negative for storage cost in the depot and flexibility.

The by far most important criterion for forwarders was number of bookings per employee. For this important criterion there was a concern that all scenarios would create more work, thus slightly negative for number of bookings and efficiency in all situations. However, there is a methodological concern here, where the fact that forwarders only listed one key criteria in the efficiency category gave it a high priority overall compared to for example within finance where there were many criteria. Thus, the analysis in the tool may have taken a bit much account of number of bookings per employee.

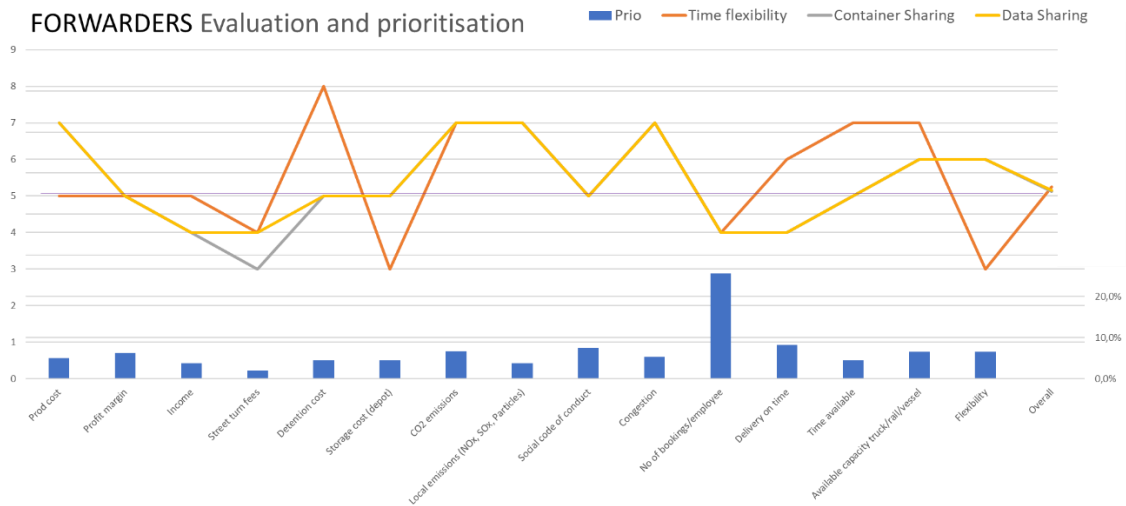


Figure 25: MAMCA for Forwarder respondents

## 7.4.4 Ports

Ports were most positive to the Time Flexibility scenario, but also positive to the Container Sharing scenario. They did not see much difference between the Data Sharing scenario and the present situation. Time flexibility and Container sharing were evaluated relatively similarly, with the exception of financial criteria where Time Flexibility was judged as more positive than Container sharing. For example, production costs, investments, profit margin and volume were evaluated as more negative in the Container Sharing scenario than the current situation.

Important criteria for ports included number of connections (rail and sea), CO<sub>2</sub> emissions, number of lifts per hour and available capacity both in terms of processing containers and depot capacity for empty containers. For the number of connections both the Time Flexibility scenario and the Container Sharing scenario were evaluated as slightly positive. The two scenarios were also seen as similar for capacity, where it would be very positive for the available capacity in depots in particular. They were also evaluated as very positive for CO<sub>2</sub> emissions. Number of lifts per hour was evaluated as no change compared to the present scenario for any of the scenarios. However, for number of paid lifts both scenarios were evaluated as negative compared to the present situation, i.e. there would be fewer lifts for the ports. It is also notable that the Container sharing scenario was evaluated as more negative compared to the current situation on all financial criteria (requiring investments, lower profit margin, higher production costs and lower volume).

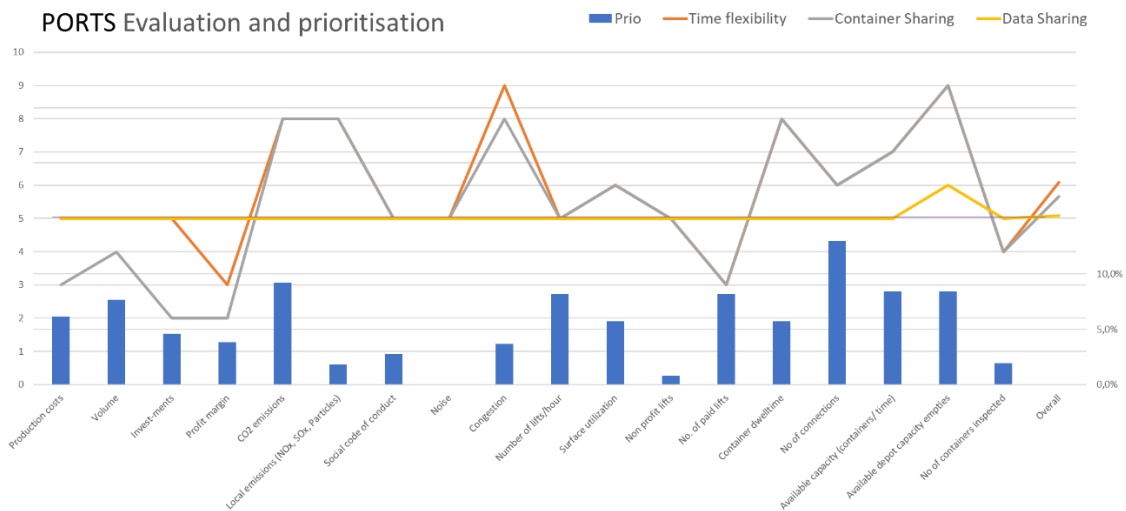


Figure 26: MAMCA for Port respondents

## 7.4.5 Shipping lines

Shipping lines were most negative to the Time Flexibility scenario, in fact evaluating it as worse than the current situation. Both Data Sharing and Container Sharing were evaluated as more positive than the current situation. It should however be noted that there were varying opinions regarding the evaluation of the Container Sharing scenario in the two workshops that were held. In general considering the average of the two workshops shipping lines were a bit more positive to how Container Sharing would influence their key performance criteria. However, two criteria were deemed as negative compared to the current situation, namely more administration and lower quality of the containers.

Important criteria for shipping lines included availability onboard, and of containers, profit margin and income from freight rates. Looking at these the Time Flexibility scenario was evaluated as negative compared to the current situation for several important criteria, such as profit margin, availability of containers and asset investment. The Time Flexibility scenario was also evaluated as negative compared to the current situation for efficiency criteria, including turn-around time and number of trips per container per year. Shipping lines expect to need a higher number of containers in the Time Flexibility scenario.

Looking at the Container Sharing scenario, shipping lines were generally a bit more positive to its effect on important criteria, such as profit margin, asset investment and availability of containers. And while more admin was seen as negative, admin was not rated as one of the more important criteria. However, when analysing in detail the responses in the two workshops varying opinions emerge, where for profit margin as well as availability of containers, the respondents in one workshop were very positive while the respondents in the other workshop evaluated it as similar to the current situation. There is thus a large variation in the evaluation here, which is important to consider. Further discussions with shipping lines revealed that container sharing is complicated due to differences between shipping lines, and very importantly the other end of the container transport, i.e. what happens in for example South America and the

responsibility of filling the container on the following leg. Thus, it has global implications.

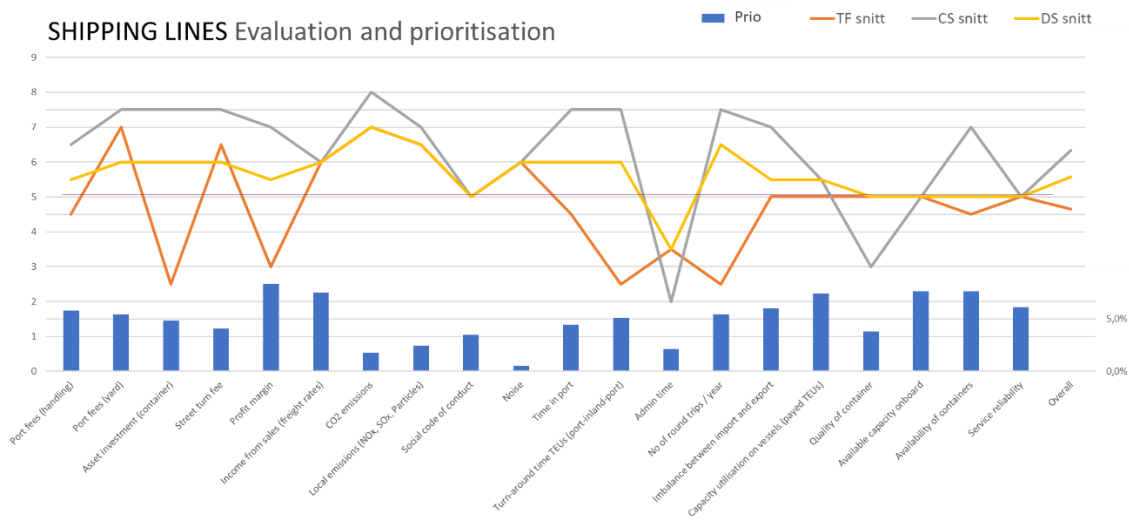


Figure 27: MAMCA for Shipping line respondents

## 7.4.6 Shippers

Shippers evaluated all three scenarios as positive compared to the current situation. They were most positive to Container Sharing and Time Flexibility. While the average for those two scenarios was similar when looking at the details there were different criteria evaluated as positive for the Time Flexibility scenario and the Container Sharing scenario. Time Flexibility was evaluated as most positive for warehouse costs, minimising admin and efficient stuffing and stripping of containers. At the same time Time Flexibility was evaluated as more negative for storage costs in terminals and delivery precision. Container Sharing was evaluated as most positive for guaranteed capacity, freight cost (both the inland leg and the ocean leg), and detention fees. Container sharing was evaluated as negative regarding admin.

Important criteria for shippers included efficient stuffing and stripping of containers, minimising admin and ocean freight costs. Considering this the Container Sharing scenario was evaluated as positive for transport costs, slightly positive compared to the present situation for efficient stuffing and stripping, but negative for admin. The Time Flexibility scenario on the other hand was evaluated as positive for the admin and efficient stuffing and stripping, but negative compared to the current situation for warehouse costs. In the workshops the shipper exporting cargo was much more positive to the Time Flexibility scenario than the shippers importing cargo, highlighting that exporters have more to gain in the Time Flexibility scenario. In particular, potential was seen to reduce demurrage fee, warehouse stuffing and handling costs, stuffing of containers and delivery reliability.

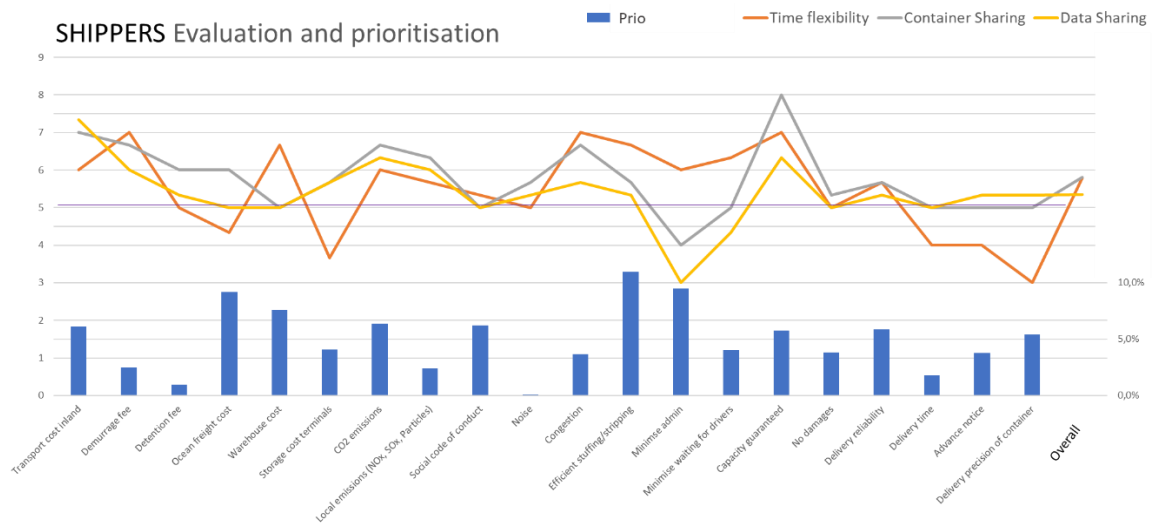


Figure 28: MAMCA for Shipper respondents

## 7.4.7 Conclusions regarding stakeholder perspectives on improvement scenarios

The overall result graph from the MAMCA (Figure 22) illustrates that there are different interests for different stakeholder groups, based on what advantages and disadvantages the scenarios bring to each stakeholder group. While the differences compared to the present situation where small they were with one exception positive. For shipping lines it was important to highlight that the scenarios are looking at a local level, while container flows are in fact global and any changes need to take the global aspects onboard.

Discussion with the stakeholders pinpointed Time Flexibility as the scenario of the three studied, as easiest to implement. However, Time Flexibility was evaluated as slightly negative compared to the present situation for shipping lines, where they expect to need a higher number of containers which has associated costs. Even so, it may be easier to allow time flexibility in situations where a surplus of containers exists. Container surplus or shortage changes over time, as was evident during Covid-19.

Difficulties related to the competitive situation were pinpointed to realise Container sharing and Data sharing.

# 8 Recommendations to stakeholders

Our results indicate that there is no one single overarching solution to solve the ECR problem. Many solutions to reduce ECR requires widespread collaboration between several stakeholders. When considering one stakeholder at a time it is possible to optimize for a single stakeholder group, while it would be better with improvements for the container transport chain overall. Bearing in mind the importance of collaboration and more than one stakeholder making changes, still information regarding the scope for each stakeholder group is interesting. Below the role and opportunities of each stakeholder to contribute to reducing unnecessary ECR is considered separately. An overview is presented in Figure 29 and additional details provided for respective stakeholder group.

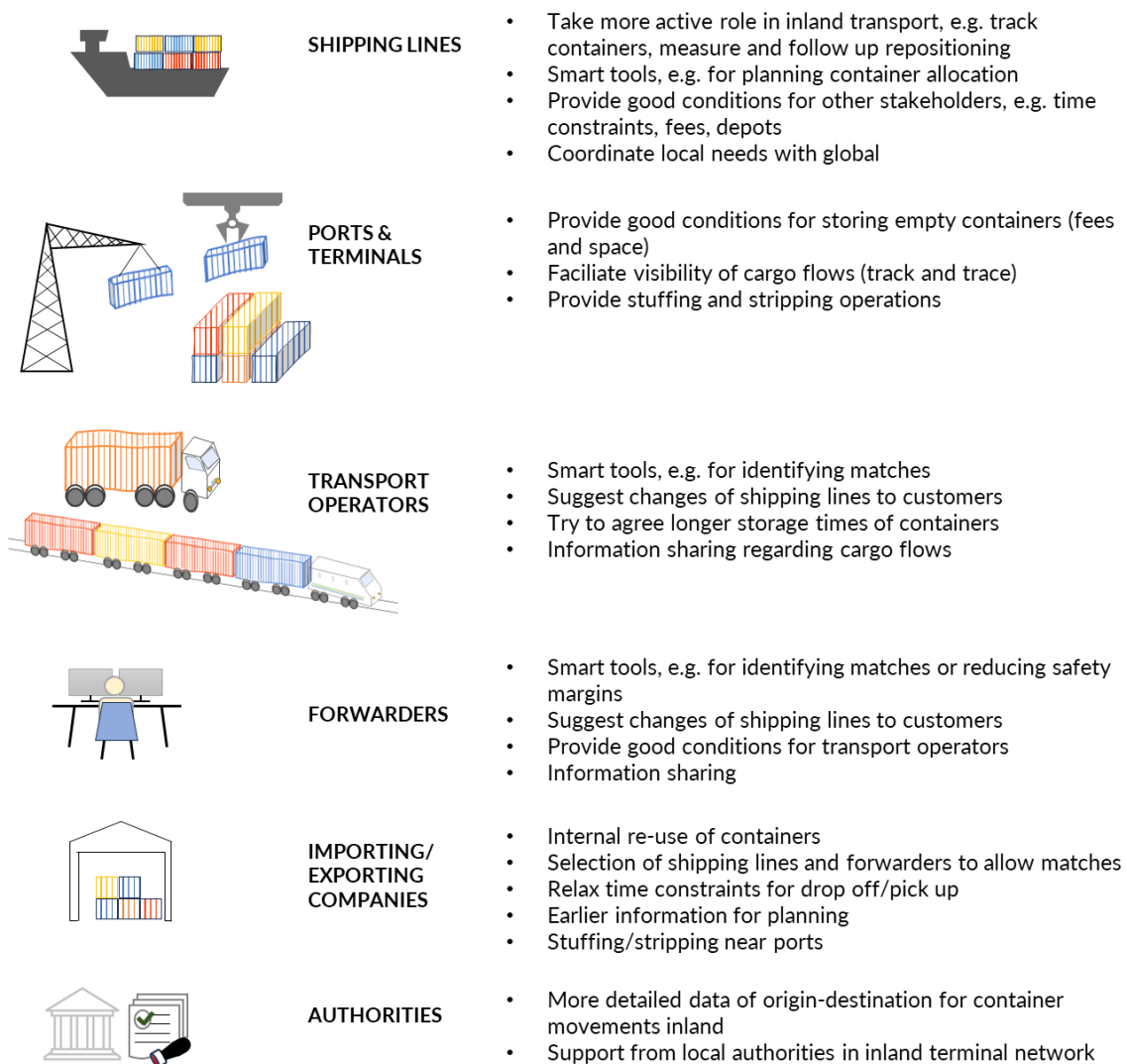


Figure 29: Overview of opportunities for various stakeholders to reduce empty container movements in Sweden

## 8.1 Shipping lines

Shipping lines own containers, and control container movements globally. They could take a more active role in local repositioning of containers. Partly it is important for shipping lines to improve their knowledge regarding containers in the inland. This can for example be facilitated by tracking containers as they move in the inland or using data provided by other stakeholders regarding where containers are located.

There is still a degree of manual planning of containers, which may be improved with systems, that may help suggest e.g. container allocation options. While shipping lines are important for realizing e.g. street turns and storage inland, it should be noted that this means additional coordination in their internal equipment planning. It is important to note that local representatives of shipping lines may act within decisions made at a global level, thus sometimes limiting local opportunities. Thus, the understanding and dialogue between local, regional and global levels is important for shipping lines. Insights regarding local prioritization might be further clarified to the global organization.

Shipping lines can also facilitate reduced ECR by setting good conditions for other stakeholders, e.g. the time allowed to return a container to the port. Recently some shipping lines have started using a web platform that facilitates the administration regarding the requests from transport operators to use the export containers and the approval from the shipping lines. Shipping lines should note that a fee for the use of such a tool can in fact reduce the incentive for street turns, at least influencing the distance for which street turn is interesting. Another way of facilitating reduced ECR is to allow depots at inland locations, however for shipping lines this means additional resources bound, and risks of additional movements between locations. Shipping lines should measure and follow up container repositioning as this may help them identify improvement opportunities.

## 8.2 Ports and terminals

For these actors, storing empty containers still generates revenues. Nevertheless, storing full containers generate higher revenues. The available capacity is always scarce and fixed in ports and inland terminals. Hence, the utilization of this space with the storage of full containers would be more beneficial for these actors. Terminal operators can facilitate reduced ECR by providing good conditions for storing empty containers, such as space and low storage fees. Seaports and inland terminals could also facilitate visibility in container transport flows by track and trace applications. Terminal operators can also provide stuffing and stripping operations, thereby limiting further transport of containers.

## 8.3 Transport operators

Transport operator already today are well positioned to identify matching possibilities to reutilize containers and find cargo in both directions, e.g. through street turns. But, the process is still largely manual, and smarter tools could be introduced that help in this identification, for example by using business intelligence even more than today. While transport operators have good information about inbound and outbound goods flows from specific locations, there are many factors that need to be considered, and these need

to be included for a successful smart tool. Such factors include driver hours, time slots, requirements on vehicle types, shipping line, weight, container type. To ensure reliability real time data regarding traffic conditions that result in replanning is also important to incorporate.

For transport operators to be successful having a wide spread of shipping lines and freight forwarders as customers is important. Transport operators can suggest to their customers that it may be beneficial to change shipping line to reduce empty movements (as it might result in lower costs). Also, transport operators can try to agree longer storage time of containers to facilitate finding more matches for emptied import containers. Further, transport operators could share information about cargo flows with others, allowing further matches between import and export containers to be made.

It should be noted that the street turn fees introduced during the project period, has the unfortunate effect that the geographical area for which street turns are interesting for transport operators becomes smaller.

## 8.4 Freight forwarders

Freight forwarders can find matches between import and export cargo in the goods flows they arrange transport for. With a larger volume in total, they are better placed to identify additional matches compared to individual importers or exporters. Here, smart tools would be beneficial to aid in the identification. However, forwarders are limited to opportunities within their own system. They can facilitate for transport operators to find matching goods by providing good conditions. For opportunities outside their own system, information sharing would be needed, and collaboration with others.

Also, forwarders can suggest to their customers that it may be beneficial to change shipping line to reduce empty movements. It should be noted that other important factors often are of higher importance for importers/exporters when they decide which shipping line.

Forwarders are concerned with the risk of delay to export customers, thereby planning for safety margins in matching with emptied import containers. Tools to help with reliability and information regarding possible delays earlier could help reduce such safety margins. Alternatively, it would be useful if shipping lines could allow extra time (1-2 days) to keep the container before matching it.

Forwarders can also help container movement planning by sharing information earlier and explaining to their customers the benefits of sharing information regarding planned inbound and outbound flows. For example, more regular flows can facilitate planning, compared to short-term buying. Forwarders can also spread knowledge regarding container management to their customers, who may have less understanding.

## 8.5 Importers and exporters

Companies importing and exporting goods may be able to minimize empty container movements by reusing containers internally. This means that import containers are reused for export. It thus only works for companies that have goods flows in both

directions requiring the same type of containers. Internal collaboration between inbound and outbound transport functions is also needed.

Importers/exporters should be more aware of the implications of their selection of shipping lines and freight forwarders, as it is within these systems that matchings between import and export containers can be made, and empty movements may be reduced. Further, importers/exporters set time constraints on both dropping of and picking up containers. If these could be relaxed it may facilitate for transport operators to find suitable matches between import and export containers, thereby avoiding empty transports to and from port.

Also, providing information earlier would facilitate planning for those trying to find opportunities for reutilization, e.g. transport operators. Transport operators get pre-advice from some importers regarding inbound containers. Making sure that information is available for planning is important, but making sure that the information is reliable is even more important for transport operators to want to base their plans on it – there the information cannot solely come from importers/exporters, but needs to also come from shipping lines.

In addition, some importers/exporters choose to have warehouses near ports, meaning that the containers only need to be transported short distances. Similarly, some shippers elect to stuff and strip containers at facilities near ports or inland terminals, which also reduces the distances containers are moved.

## 8.6 Authorities

There are several things that the authorities can do to improve ECR processes in the hinterland. First, it is important to calculate the actual potential. Accurate data is required to do that. National transportation authorities can introduce new rules to encourage involved actors to share origin-destination data for container movements in the hinterland. This data should be available for both full and empty containers. Transport authorities can also develop systems to declare such data in a seamless manner in order to generate databases that span over the years. Such data would be beneficial in terms of calculation of improvement potential as well as illustration of low or high capacity utilization based on origin-destination pairs. Such a database can function as case examples and showcasing improvement potential can act as a facilitator and encouragement for more inland transportation actors to adopt beneficial ECR strategies.

Most of the time, local authorities subsidize inland terminals and they have a stake in the establishment and effective operation of such infrastructure. Considering the potential of extended storage at inland terminals for improved ECR, these local authorities can initiate programs, invest in storage space, invest in trial and facilitation of extended storage for street turns via inland terminals within their management area. Such examples can extend the use of this strategy to other regions.

## 9 Conclusions and further research

The empty container repositioning process in the hinterland includes several steps performed by multiple actors. Shipping lines, ports, transport operators, freight forwarders have all an important role to play in reducing the empty container repositioning in the Swedish inland transport system. The driving forces to reduce empty container repositioning is in particular related to financial and environmental aspects, while barriers are both structural, operational, financial and market-related.

There is a limited knowledge of empty container movements by road in Sweden. This project used both the commodity flow survey (CFS) to understand the asymmetry of freight flows and the truck dataset to characterize empty containers truck trips. The analysis of the truck dataset at the national level showed that about 12% of truck trips are container trips. From those truck container movements about 45% are empty containers, and about 77% of those empty trips are within the same county.

Given the lack of knowledge about empty containers movements, this project developed a payload model using the CFS data to obtain the number of loaded trips between counties, and an empty trip model calibrated using the trucks dataset to estimate the number of empty container truck trips between counties. Along with the models, the main findings from the modeling efforts are:

1. there is a lack of integration in the container trips data: national road trips surveys are disconnected from international trips and from intermodal trips, and there is limited connection between commodity flows and container trips
2. Empty container trips tend to be shorter than loaded container trips
3. Most empty container truck trips are generated by freight transport by road (SNI 49410), but activities in sectors such as site preparation (SNI 43120) and renting of construction or demolition equipment (SNI 43991) can lead to share of empty container movements larger than 50%
4. The county of origin and destination of container road trips are good explanatory factors explaining the share of empty containers

Even if there is a lack of data the modelling efforts show a large proportion of empty container trips performed in the transport system, thereby the potential of improvements to be investigated further. The project has investigated several suggestions for improvements, related to locations/routes, containers and ownership/regulations/agreements. An overarching theme for solutions within these areas is the need for coordination between actors. In particular, three promising strategies for improvement was investigated in case-studies with quantitative analysis. These strategies were 1) to use rail transport to/from the sea port via inland terminals, 2) foster reutilization of containers by matching import and export containers and 3) triangulate between inland terminals.

In terms of empty container movements by rail, the assessment of re-utilization of empty containers within a same inland terminal and triangulation across terminals showed a significant potential to reduce the number of containers in the system and the amount of

empty containers movements. A system-level optimization from the perspective of one of the major ports of Sweden shows that re-utilizing containers and triangulating containers across inland terminals can lead to about 26% reduction in the amount of empty containers required.

Even when looking at isolated triangles, by connecting two compatible inland terminals it is possible to achieve savings of between 31 and 55% in container-kms and 60% in energy and emissions savings.

When studying empty containers movements locally, i.e., in the surroundings of an inland terminal, the simulations showed that it is possible to match 27% of export containers so that they come directly from imports. This matching can lead to street turns that reduce emissions by about 6%. However, if the free temporary storage time is extended to 10 days, the share of export containers coming from import operations increases to 54% and this can lead to between 13 and 17% in cost and emissions savings.

It is noteworthy that all the numbers presented in these conclusions assume that there is no collaboration between shipping lines. Collaboration between shipping lines even when limited to alliances can lead to significantly bigger savings.

The Multi-Actor-Multi-Criteria-Analysis (MAMCA) that complemented the quantitative analysis showed the actor perspectives of three strategies that were developed based on the case results, namely *time flexibility*, *container sharing* and *data sharing*. All of these three scenarios would support the potential reduction of empty container repositioning. The MAMCA showed some varying perspectives on the scenarios from the different actors but most importantly the results showed that all scenarios were perceived similar or better than the present situation by most actors, which would indicate a potential for realising the scenarios. Time flexibility was indicated as easiest to implement. Still, there is a need to further investigate if the driving forces are strong enough for all actors that need to be involved. There might be specific circumstances that will make the scenario more or less valuable for the actors. For example, global aspects of the container flows need to be considered. All in all, we conclude a number of recommendations to the stakeholders that would facilitate the reduction of unnecessary ECR.

For further research, the following areas are important to highlight based on the project results:

- To develop data sets for national statistics, e.g. for road goods data include the type of container and OD pairs at municipality level, and for CFS data differentiate between containerized and non-containerized cargo for each mode.
- To develop smart tools for information sharing to optimize match backs between importers and exporters, e.g. building on data needs identified in Gustafsson and Rogerson (2023)
- To take a larger system perspective of the global ECR and set that in relation to actions that can be taken on the local level.
- The implications of vertical integration on ECR, i.e. shipping lines taking a door to door transport responsibility.

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