18 Improving Empty Container Logistics – Can it Avoid a Collapse in Container Transportation?

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Abstract

Since the introduction of the maritime container in the mid 1950's, liner shipping groups have migrated from inefficient traditional cargo handling techniques to large cellular vessels which can be seen at any of the world's major ports today. The use of the container improved intermodal productivity and allows for shorter point to point transit times. In addition, cargo damage is reduced. On one hand, shippers and carriers have benefited enormously. On the other hand, they are faced with increased operational complexity as well as a multitude of variable and fixed costs. Managing these is important in particular in situations with intense competition in turbulent financial times. Moreover, the increase of the container population as well as an increasing global trade imbalance resulted in accumulation of empty containers (or empties) in some major port areas and container shortage in other regions. In this paper we consider the problem of empty container management (ECM) / empty container transportation and discuss solution concepts to overcome parts of this situation.

18.1 Introduction

Participants in the global shipping industry are almost always faced with trade imbalances since both North America and Europe have a trade deficit, in particular with China which is still leading the growth in cargo flows. Apart from the current global crisis which led to a general drop of the global trading and transport volume, the cargo volume has increased throughout the last years. The containerisation up to 2008 as well as forecasts for the next decade show a clear trend upwards (see Figure 1). A chronic issue of container transportation inherent to the system is an empty container imbalance on different regional levels. Generally, an increase in volume leads to even larger volume imbalances, i.e., large export flows from Asia to North America and Europe with smaller import flows to Asia (see Figure 2).

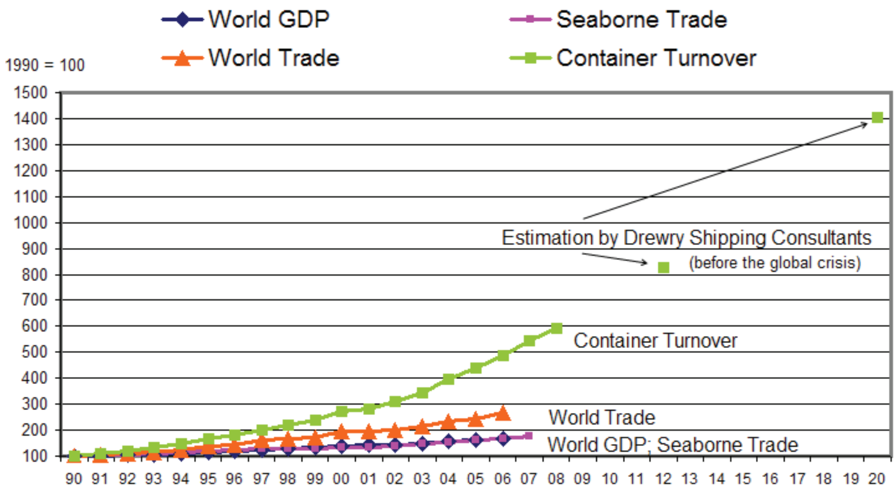

Figure 1 World GDP, World Trade, Seaborne Trade and Container Turnover
Data retrieved from Volk (2002) and UN Conference on Trade and Development (UNCTAD) – Secretariat (2008)

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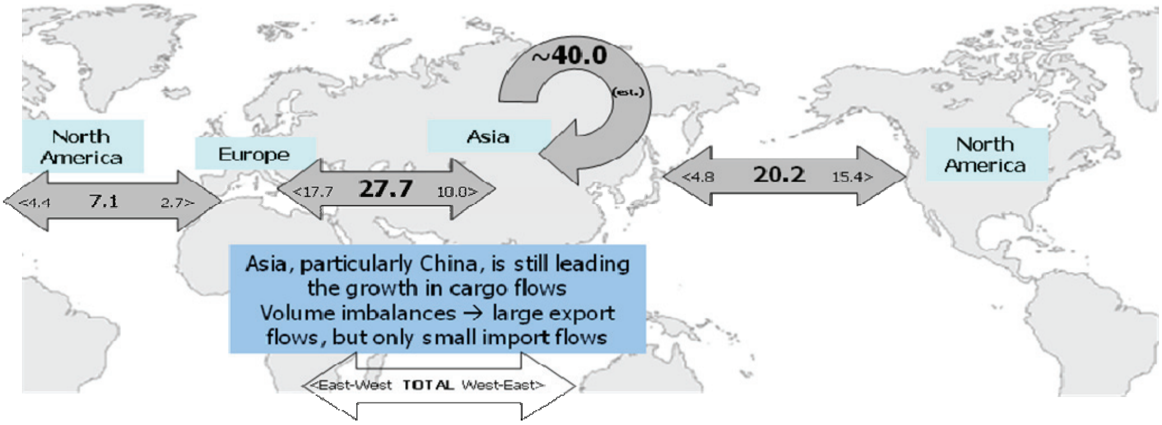

Figure 2 Traffic of main global containerised cargo routes 2007 (million TEU)
Data: United Nations Conference on Trade and Development (UNCTAD) – Secretariat (2008), pp. 23-25

On the transpacific route, the volume imbalance in 2007 was 1 to 3.2 in favour of eastbound traffic. On the Asia-Europe route, the volume imbalance was 1 to 1.8 in favour of westbound traffic. The imbalances are caused by disconnected manufacturing of mass consumption goods of export-oriented economies and large consumption markets such as North America and Europe. Compared to the Asian segment the transatlantic containerised trade between Europe and North America has become a low volume market. Furthermore, the container port throughput is more than three-fold the trade volume since a given trade movement (import or export) involves more than two port moves. The explosion of trade in containerised maritime transportation causes an increasing pressure on leading sea ports. Major challenges of the coming years will be (among others) trade imbalances as well as congestions within terminal and port areas including connections to the hinterland.

With a larger imbalance, the incidence of empty containers result in increased handling costs for empties caused by, e.g., repositioning operations, cabotage restrictions, and empty mileage. Additionally, while a considerable part of Asian exports are high value products such as computers, consumer electronics, clothing, etc., a lot of containers going to Asia are filled with waste paper and scrap metal making an otherwise empty container a laden one without nearly paying true shipment costs. With respect to costs, there is only little (or no) saving in handling or carrying an empty box instead of a laden one. Therefore, liner carriers have to address imbalances and their implications for empties. As Robinson (2007) points out, the costs of moving an empty container from the US to Asia or Europe is virtually impossible to determine since slot costs are usually a mixture of indirect costs related to ship financing and opportunity costs and direct costs related to trucking, handling and storage. According to Drewry Shipping Consultants (2002), the costs of repositioning are $400 per empty container. Obviously, a part of these costs depends on the level of freight rates. Note that containers are empty approximately (or more than) 50% of their total cycle time due to maintenance/repair, storage, and transit. The total cost of empty container handling is assumed to be in the order of $5 - $10 billion per year or, from a container shipping line's perspective, equipment and repositioning costs add up to about 20-25% of their total costs. Hence, efficient ECM is very important for a shipping line in the highly competitive market. The need for cost savings is high – as well as the potential. There are additional imbalances with respect to transport costs as well as container types and investments. For example, in June 2007 the transport for one box from China to Rotterdam was $1,600 whereas the transport in the opposite direction was only $350. Although freight rates dropped dramatically due to the global crisis, the general discrepancy remained. An example of a container type imbalance is mentioned in Robinson (2007): a large number of 20ft containers are imported into the UK from China, whereas most of the opposite export traffic is in 40ft containers. With respect to infrastructure, the growing imbalance in supply and demand in Pacific container shipping is reported in Stalk and Waddell (2007):

'Over the next several years, close to 100 new container-loading berths will be built in China, each with a lift capacity of about half a million TEU per year. […] Yet over the next several years, no more than five new berths are planned for the west coast of North America.' The utilisation of main ports is on the order of up to 90%. Many ports are unable to expand since surrounding communities resist growth and rail capacities are nearly maxed out. Therefore, they have to improve their productivity by means of new handling concepts. One solution is to use dry port concepts, i.e., relocating port operations into the hinterland. A different approach might be the use of better planning and scheduling tools as well as animating technologies such as foldable containers. Finally, the current global crisis results in even more pressure for improvements in order to increase efficiency and reduce costs.

In this paper we deal with ECM from various perspectives. In Sect. 18.2 we provide a brief literature review and then we focus on a few specific concepts that may help to improve the situation. Sect. 18.3 is devoted to the concept of foldable containers. Sect. 18.4 looks at (mostly quantitative) approaches for reducing empty container transportation and storage costs. One of the major problems might be the discrepancy between the wealth of data available for analysing the container market and the fact that this data is not properly used by shipping companies as well as port actors. In Sect. 18.5 we provide a brief sketch of ideas to overcome this. The paper concludes with some final remarks.

18.2 Literature Review

Scientific literature regarding the management of empty equipment is abundant but it is primarily focused on the optimisation of equipment transportation and on particular areas of the distribution cycle. The dynamic allocation, distribution and reuse of empty equipment for balancing demand and supply among terminals is extensively discussed, even in the context of network design problems. Furthermore, research on the effect of the planning horizon length is done as well as on finding the optimal amount of storage space in a yard. ECM is also treated as an equilibrium inventory problem. Some studies analyse stakeholder operational activities, too. Almost all studies assume that the destination ports of empty containers have to be determined before the boxes are loaded onto vessels. One research gap until now seems to be an investigation of a strategy using flexible destination ports. According to the systems that are considered, the literature can be classified into studies focusing on deterministic systems and stochastic or uncertain systems such as inland empty container allocation or port-to-port container repositioning. Taking different regional levels of planning into account, local and global approaches with different objectives can be distinguished. With respect to adopted techniques, studies using mathematical programming can be distinguished from studies applying parameterised control policies. The former studies focus on, e.g., the selection of an appropriate planning horizon, the latter ones investigate, e.g., characteristics of different empty repositioning policies.

Several studies are performed for gaining a better understanding of the important and complex problem of efficient allocation and distribution of empty containers. Allocation and distribution are processes of assigning activities (e.g., costs, facilities, equipment) and ensuring their availability in the quantity, quality, place and time desired by a customer. Dejax and Crainic (1987) find in their survey paper that most of the work on fleet management models in freight transportation was focused rather on maritime aspects than on developing specific models for land container transportation. Efforts in that area addressed mainly the distribution of empty containers, i.e., the allocation of containers to demanding terminals (e.g., different marine terminal, customers' warehouse, rail yard). Crainic et al. (1993) describe the problem of dispatching empty containers of various types to storage depots or ports. Two dynamic deterministic formulations for the single and the multi-commodity cases as well as a general modelling framework for this class of problems are introduced.

More recent works include Shen and Khoong (1995) and Cheang and Lim (2005). In both cases the focus is on decision support systems (DSS) for solving the empty container distribution problem.

Di Francesco et al. (2009) address a container repositioning problem with several uncertain parameters and data shortage. They propose a time-extended multi-scenario optimisation model in which scenarios reflecting shipping company opinions can be generated. Two different types of ports are considered for taking different restrictions regarding the storage of empty containers into account.

Most of the papers regarding empty container repositioning require a pre-specified planning horizon. Choong et al. (2002) present a computational analysis of the effect of planning horizon length on empty container management for intermodal transportation networks in a deterministic system. Both long-term and short-term leased containers are used and modelled in the same way as company-owned containers. The cost of the short-term leased containers is independent of the lease term. Three different modes (truck, rail and barge) are considered in the analysis. Cheung and Chen (1998) consider the dynamic empty container allocation problem. They address the need to reposition empty containers as well as to determine the number of leased containers (long- and short-term) to meet customers' demand over time. The model supports liner operators to decide on the allocation of their empty containers for reducing their leasing cost and the inventory level at ports. Crinks (2000) as well as Behenna (2001) emphasise the need for increasing the equipment visibility among ocean carriers since carriers, shippers, and vendors find it difficult to manage their assets effectively due to the information gaps or 'blind spots' along the transport chain. Container operators are prevented from realising all possible equipment management options currently available to them (e.g., interchange or triangulation) and are hindered to realise a more efficient equipment usage. It is noted that approximately $100 billion are spent for container handling and asset management, and it is estimated that approximately $16 billion of that are attributable to the costs of repositioning empty containers only. It is concluded that the greatest opportunity for reducing costs by increasing the equipment visibility is during blind spots on the landside when the assets leave the ocean carrier’s network. One of the options to improve related data availability goes in line with an increased use of port community systems; see, e.g., Van Baalen et al. (2008).

Jula et al. (2006) study empty container movements in the compact transportation network of the Los Angeles and Long Beach (LA/LB) port area. They aim at reducing congestions by optimising the empty container reuse in a deterministic system. Containers are directly distributed among customers without necessarily passing through container terminals, i.e., without a central distribution mechanism. Olivo et al. (2005) propose a mathematical programming approach for empty container management modelled as a min cost flow problem with arcs representing service routes, inventory links and decisions concerning the time and place to lease containers from external sources. The proposed algorithm shows a good computational efficiency even for large-size instances with an hourly time-step in a dynamic network. Dong and Song (2009) focus on the joint optimisation of container fleet sizing and empty container repositioning in liner shipping systems, i.e., multi-vessel-, multi-port and multi-voyage shipping systems with dynamic, uncertain and imbalanced customer demands. Their simulation-based optimisation approach aims at minimisation of the expected total costs by applying GAs and evolutionary strategies for simultaneously finding a container fleet size and repositioning policy. Bandeira et al. (2009) present a DSS for the integrated transhipment of empty and full containers based upon a network model with nodes representing incorporated actors and arcs representing transportation routes. In a first stage, the model assigns priorities and adjusts full container demands taking available empties into account. In a second stage the model statically minimises total costs (transportation, storage and handling). The static solution provides routes in a time schedule which are dynamically controlled until containers arrive at their final destination.

18.3 Reducing Empty Container Transport, Transport Costs, and Other Ideas

Reducing transport and storage costs can be achieved by influencing the transport and storage directly by striving to avoid transport movements or to make the best of the fact that empty transports cannot be avoided or significantly reduced by, e.g., applying appropriate pricing strategies and influencing actual transport costs. One simple idea to reduce empty container transport costs is to use spare capacities on a vessel (in particular in times when supply of capacity exceeds demand) by filling empty slots with empty containers in order to balance surplus and deficit in the respective areas of the vessel’s route. This concept can be enhanced in a carrier cooperation scenario with the deficit of one carrier being covered by the surplus of a different carrier resulting in a win-win situation. One option with respect to pricing is to compensate repositioning costs by charging a higher freight rate on the opposite leg with high demand. For mitigating rate increases in the high demand leg, generating cargo flows in the low demand leg would be useful. Another option is to offer incentives to shippers to make them use specific equipment resulting in lower costs for the carrier.

Boile (2006) categorises approaches for responding to the empty container problem into managerial solutions, policy solutions, logistics solutions, IT solutions and container technology solutions. These approaches keep the empties a part of the intermodal transportation system. Furthermore, empties can be seen as attractive commodities for marketing resulting in approaches to focus on secondary uses of empties and, e.g., utilise them for habitation. Depending on steel costs, costs for manufacturing containers, and costs for the recycling process itself, the recycling of empties can be an appropriate solution, too. Managerial solutions comprise, e.g., grey box pools (i.e., combined container fleets of cooperating carriers), box swapping (a cooperative box match concept), box passing to carriers after expired lease, horizontal diversification, and yield management. Policy approaches comprise, e.g., various taxation schemes for containers stored for more than a certain period of time, limiting the height at which empty containers may be stored, or changing the equipment depreciation period. Logistics solutions primarily aim at controlling the inland part of intermodal container transport. IT solutions are nowadays typically web-based approaches in order to provide better visibility of equipment. Container technology approaches could focus on collapsible containers. Commodity approaches may consider secondary use of empty containers, e.g., as houses for living, classrooms, lavatories, restaurants or gas stations.

18.3.1 Foldable or Collapsible Containers

Konings (2005) and Shintani et al. (2010) discuss the opportunities for commercial application and cost saving effects of foldable containers and discuss conditions for their successful operation. (Examples for different concepts are shown in Fig. 3 and Fig. 4; see also HCI (2010) or even http://www.youtube.com/watch?v=QWLfsMIGDic or http://www.youtube.com/watch?v=wjFbmrI_cGc.) In the first paper, four logistic concepts are presented as a framework for a cost-benefit analysis and compared with the use of standard containers. It is shown that foldable containers can result in substantial net benefits in the total chain of container transport due to their potential for saving costs. Without considering the complexity of real-world container transport chains in detail, it is demonstrated that using foldable containers in a land leg of a transport chain provides a larger potential of cost savings than using them in the sea leg. Costs of (un)folding, additional exploitation costs and costs for any additional transport to places where (un)folding can take place have to fit into respective available financial margins. It is concluded that there is a major challenge for designers and producers of containers to develop a foldable container that can be operated within the financial margins.

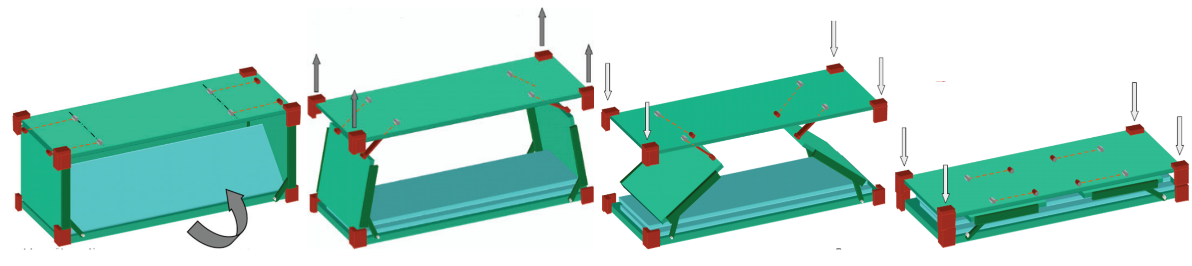

Figure 3 Concept of the foldable container of Holland Container Innovations (Source: HCI)

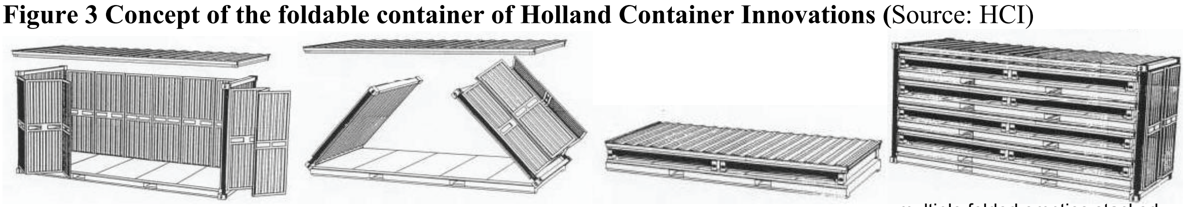

Figure 4 Folding process of the Fallpac Container (Source: Fallpac AB)

18.3.2 Suggestions for Further Innovation

An extended literature review shows that the empty container accumulation problem is well recognised in science and industry. However, most papers either focus on isolated components of the problem trying to solve them separately or they treat this problem as a side issue. Focusing on separate aspects of the entire problem helps to gain insight and therefore supports the development of an approach considering all components and solution strategies for this integrated problem. Our ideas on improvements of the transport chain in terms of time and/or cost reduction are focused on separate components, too.

Mainly based upon the papers of Konings (2005) and Shintani et al. (2010), the concept of foldable containers could be further developed in order to gain a net benefit of their usage. One idea might be folding on the spot since one of the crucial assumptions in the above mentioned studies refers to additional costs caused by additional effort of folding and unfolding and for transport to locations where (un)folding can take place. However, no extra location for (un)folding operations is required if foldable containers are designed in a way that they can be folded (or maybe even dismantled) on the spot. Hence, we have a different situation since no additional costs for transport to a particular handling area incur. We suggest that it is possible to process the folding/dismantling operation in connection with the twistlock operations. A basic idea is that the spreader of the crane folds the container automatically ('on the fly'), e.g., when locating it in the vessel's body. This might be an interesting challenge for engineers.

It might also be fruitful to consider ecological issues related to reverse logistics. Assuming that empty container transport cannot be completely avoided, a better usage of this necessary transport of containers occupying expensive vessel slots should be considered. For example, it might be useful to embed those transport capacities into a global reverse logistics chain, notably including scrap, waste/recycle paper, and similar objects as mentioned above. In addition, developing and using one way containers for single use only might be an interesting approach to be analysed. Developing a 'throw-away container' without negative ecological effects is again a challenge for engineers. Maybe there is a net benefit of using, e.g., cardboard containers which are shredded after use. The raw material can be transported to the most cost-effective locations for manufacturing new containers. Apart from the specific problem of empty containers, one could strive to reduce the transport costs in general by, e.g., making use of automation and innovative technologies such as SkySails or CargoRail. Furthermore, the idea of advanced intermodal concepts and shipping centres, satellite terminals, or dry ports in the hinterland which concentrate containers and handling processes is worth to be analysed in more detail, too.

18.3.3 Empty Container Management and Data Mining

The application of data mining techniques can be helpful for liner operators and container terminals for gaining insight into processes and problems of container handling and particularly in ECM. Terminals perform similar functions, but the processes, technology, and labour requirements differ at each terminal. Therefore, terminals are faced with different bottlenecks. Due to the complexity of terminal operations it is difficult to identify bottlenecks within a process. For liner operators, the management of their equipment is difficult due to the forecast uncertainty with respect to future demand and supply of empty containers. In addition, the planning process has to take different regional levels with surplus/deficit and respective actions for balancing into account. On one hand, the large amount of transaction data and the large number of potential, interdependent factors make an analysis challenging. On the other hand, having a large database is a prerequisite for using promising and well established data mining methods, such as decision trees, neural networks, support vector machines, or association rule analysis in order to derive knowledge from data reflecting processes and patterns. Data mining algorithms are useful for analysing data, identifying problems, interpreting solutions as well as for forecasting. For example, forecasting the movements of full and empty containers on a terminal-wide, regional or even more aggregated level can be helpful for equipment planning purposes. Classifying time series of equipment demand or container flows by means of an ABC/XYZ analysis (reflecting importance/criticality and predictability) as well as considering calendar effects on a detailed regional level and seasonal patterns regarding the demand of specific container types in different regions can provide useful knowledge for forecasting equipment demand and controlling equipment flows. Decision tree based approaches can help to interpret data and identify causes for inefficiently performed processes (e.g., Huynh and Hutson (2008) show an application of decision trees for analysing abnormal high truck dwell times within a terminal). Although there is a lot of scientific literature on either container logistics or data mining, there are only very few publications combining both research fields (e.g., Li et al. (2008), Peng and Chu (2009)), but they do not discuss ECM. This seems to be a remarkable research gap, especially when 'blind spots' regarding data availability once full containers are transported into the hinterland need to be filled. The analysis and application of data mining techniques for solving container related problems and supporting decision makers seems to be fruitful for researchers as well as practitioners.

18.4 Conclusions

This paper addresses the problem of empty container management, one of the major issues following world-wide trade imbalances. Currently, various streams of research are somewhat isolated in literature. There are quite a few promising decision support systems available for reducing empty container transportation. Moreover, there are solution concepts to overcome the major drawbacks of empty container management which are not popular in practice (like, e.g., the use of foldable containers). Economical and technical conditions for promising usage are considered together with ideas for improving them. Ecological issues related to reverse logistics (e.g., scrap, waste paper/recycle) are taken into account and we have also proposed other ideas like the extended use of data mining in empty container management, especially regarding hinterland operations. Future research should not only combine the different streams of research but also implement (some of) them in practice. For this it might be necessary to put the classification and solution approaches for empty container management on a higher level so as to allow for better synthesis and deduction of implications.

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