1. Introduction

Freight transportation has always been an important socio-economic activity. Such an industry influences the economies of many countries, plays a fundamental role in the support of industrial and commercial processes and significantly affects a part of a product's final cost. However, in a highly competitive environment, the diversity of actors involved and the necessity for transportation firms to satisfy customers' requests with suitable solutions in terms of economic efficiency and service quality increases significantly the complexity of a transportation system.

In recent years, there has been not only a change in hauled goods, but also an evolution in cargo handling techniques. Some characteristic aspects of this change are globalization, the development of containerized maritime transport and intermodality. Globalization constitutes an essential characteristic of freight transportation management. Nowadays many firms have set up productive activities with sales bases all over the world and, for this reason, they need an efficient, reliable, convenient transportation service that is organized on a world-wide scale.

Full container ships allow the creation of such a transportation service, so finished or seed-ended products can be produced in the most convenient place and hauled without difficulty to the locality where they will be consumed or used in production. The successful use of containers is attributed to the economies of scale deriving from the reduction of an almost endless number of shapes and dimensions of goods to a small number of standardized units. Containers also offer the great advantage of security and facility of handling.

The introduction of containers was not only a mere technical change, but a true revolution that has transformed transportation activity from a service port-to-port to a door-to-door based on intermodality, where the carrier ensures freight transportation from the initial shipper to the final recipient through two or more modes without cargo breaches.

However, even for products having little worth, for which other efficient techniques of transport exist, it is convenient to resort to containers, particularly when the carrier needs to reallocate many empty containers on the market and, therefore, is willing to practice extremely convenient prices in order to avoid these unprofitable movements. The goal of this paper is to describe the issue of empty container management on the world wide scale, addressing some specific characteristics (for instance the need to use them frequently and to allocate them suitably in order to provide new transportation opportunities) and mentioning interesting research trends in order to improve the state-of-the-art reached by Operation Research in this issue.

2. The Context

The management of empty containers is probably the issue of greatest concern to transportation firms in dealing with the distribution of goods on behalf of their customers on the national or international scale. In their industrial and commercial activities some customers need to import goods and, when they require a containerized service, loaded containers are hauled with the required products toward their firms. Transportation modes are truck, rail, ship and barge and, since a door-to-door service is usually provided, the first and last movements are generally performed by truck.

Once loaded containers reach their final destination, they are unloaded and the empty containers are taken to a port or depot, awaiting future requests.
Other customers must instead ship their goods, so they require one or more empty containers, which are taken to the customer company, loaded and shipped to their final destination, in accordance with classic door-to-door service. Also in this case empty containers must finally be reallocated in an opportune depot, awaiting future requests. The movements described are illustrated in following Figure 1.

![Diagram of container movements](image)

**Figure 1.** Loaded and empty movements of containers between a port and customers.

Figure 1 is clear, but also too simple to reflect a real situation: indeed, empty flows can also take place in other situations, such as in the container’s movement to/from repairing areas, to/from trade partners or in the purchase of new containers. Moreover, empty containers are sometimes kept in the carrier’s inland warehouse (e.g. rail yards), where the transportation firm rents the space it needs.

In the situation described it is essential to emphasize the economic difference between loaded and empty flows. On the one hand, loaded movements are in response to customers’ requests and they must pay for such a transportation service. On the other hand, empty movements generate only costs and constitute an unavoidable phase in the freight distribution process. As Figure 1 shows, every profitable movement of a loaded container generates a non-profitable empty movement, which is however essential for the continuing operations of transportation firms.

The need to maintain competitiveness in the freight distribution market and the existence of several secondary problems related to empty container management make this aspect particularly relevant. Managers must indeed address strategic/tactical issues (e.g., the selection of depots, the allocation of customers to depots), medium term problems (e.g. choose the best spatial and temporal distribution of empty containers satisfying known and forecasted demands) and deal with day-by-day operational models regarding the determination of modes and routes for the simultaneous management of loaded and empty containers (Crainic and Laporte, 1997).

It is also interesting to point out that, compared to loaded flows, the implementation of empty flows gives more freedom to carriers. The transportation of a loaded container has indeed a fixed origin, a fixed destination and, sometimes, a fixed schedule, while empty container reallocation does not have specific origin-destination demands and usually no specific time schedule. The only requirement is to satisfy customer requests, given the supply of each container type (Joborn and al., 2001).

The scheme proposed in Figure 1 becomes difficult when the commercial traffic in a port is unbalanced, that is, when imports prevail by far over exports or vice versa. In the first case a port tends to accumulate an increasing number of empty containers in its yards, while in the second case, the port has to deal with a shortage of empty containers, that it needs for exports. Thus, the difference between export and import containers corresponds with significant balancing of flows of empty containers between areas served by a transportation firm. In a perfect world empty movements would not exist, because there would always be cargo to fill every container when and where it is emptied. However, commercial traffic never seems to be in balance, either in volume or value, and it becomes necessary to proceed to the reallocation of empty containers on the global, national and local scales.

Empty container management becomes an important problem on the world-wide scale: transporting air in a heavy steel container from one part of the world to another is not a practical activity and it is surely not a profitable way to do business, because the cost of such unavoidable movements are quite high. In 1999 it was estimated that the handling cost of empty containers was more than 25 billion U.S.A. dollars worldwide and that, if that tendency had persisted, this cost would have gone beyond 50 billion dollars a year by 2010. Moreover, it was estimated that the cost of providing mooring infrastructures and indoor yards for holding empty containers would call for billions more. (Source: Jarman M.V., 1999). In this situation, since empty flows are simply a loss, the system cannot afford to absorb this added expense without shippers expecting to see at least a partial offset of these costs through higher rates for loaded movements.

The resources spent for such operations are becoming an aspect of primary importance for containerized trade, so it is not surprising that several firms are examining the possibility of reducing the incidence of these unproductive but unavoidable costs. Nowadays, at a time of slim profit margins, managers are of the opinion that proper management of empty containers may represent a decisive competitive edge for a company or, at least, allow its survival on the market.

The reasons that have imposed the necessity of transporting so many empty containers are not a secret: they are the result of economic pressures that have reduced the buying power of many Asian currencies, making Asian products cheaper for American and European consumers and at the same time reducing Asian imports from Europe and the United States and increasing exports. Looking at the following Figure 2 (source P.M.A Update, 1998), which shows in the upper graph the monthly difference between discharged and loaded containers and in the lower one the total of all discharged and all loaded containers on the American West Coast, it is interesting to note that during 1995 and early 1996 discharged and loaded containers were nearly in balance, and for several months loaded TEUs exceeded discharged TEUs. This period corresponded closely to a period when the Japanese yen and other Asian currencies were very strong against the U.S.A dollar.
Thus there has been a strong mismatch between ports and depots of the United States and Europe, where empty containers tend to be accrued, and those of the Far East, where empty containers need to be reallocated. So terminal operators of Europe and the United States have been forced to organize the storage of empty containers in high blocks. However, it is important to note that the accumulation of a growing number of idle containers in a yard is not an asset for a port, which thus needs to create new structures in order to ensure their storage: the expansion of terminal containers – as shown by the cases of Singapore, Hong Kong and Rotterdam – has cost many millions of dollars, with the occupation of lands having a high land value, adjacent to port zones which otherwise could be used more profitably by industry.

In order to effectively represent the imbalances in worldwide commerce, we present the demand positions of the three main East-West trades (Asia/North America, Asia/Europe and North America/Europe), that are estimated to have generated approximately 44% of world container traffic (Source: Mitsui O.S.K. Lines, 2001).

Table 1 refers to the quarterly data regarding trade between Asia and North America, which constitutes the most critical situation as concerns high unbalanced cargo volumes. To illustrate the current foreign container trade imbalance on the American West Coast, the P.M.A. calculated that only in the first six months of 1998 more or less 500 ships with a capacity of 3.000 TEUs each would have been needed to move all excess empty containers back to Asian trading partners.

These drastic forecasts for the short period will probably be cushioned by several positive factors that will help to prevent further widening of the supply/demand gap, such as China’s entry into the W.T.O. and the official trade agreement between the U.S.A. and Vietnam. Moreover, the unpredictable long-term effect on the world economies of the terrorist attack in the U.S.A. adds a great deal of uncertainty to all forecasts. Table 2 concerns quarterly data on trade between Asia and Europe. Although in the past Europe has always exported more containers than it imports, the current predominance of westbound traffics against eastbound traffic is shown.

However, the interpretation of these data is not so immediate because goods transferred in the two directions are often of different kinds and therefore require a different type of container. Indeed, for eastbound freight transport 20-foot containers are mostly employed, while for westbound traffic 40-foot containers are generally used. Hence a suitable model for the container management problem should have a multicommodity formulation, where each container type is represented by a different commodity and partial substitutions are allowed among various container types.

Table 3 refers to quarterly data regarding traffic between Europe and North America and shows that westbound container volumes from Europe to the U.S.A. continue to be substantially greater than container volumes in the reverse direction, thus generating considerable incremental costs to carriers in the repositioning of containers towards Europe, where they are needed to serve the westbound market demand.
The O.W.L (Ocean World Line) has assessed that during the first half of 2001 the imbalance between North Europe and the U.S.A. was about 203,000 TEU which is 27.21 percent of the 746,000 TEU sent across to the U.S.A. In Mediterranean trade, American imports were 356,000 TEU while U.S.A. exports were 134,000 TEU only, thus creating an imbalance of 222,000 TEU, which means that 64.16 percent of American imports had to be handled empty. Recently the equipment imbalance has been partially alleviated by the appreciation of the euro against the U.S.A. dollar, so European products have become more expensive in the U.S.A. and American goods cheaper for European consumers, thus reducing American imports and increasing exports towards the old continent.

However, in order to provide a more detailed representation, it would be better to take into account that Atlantic ports are also affected by trade imbalances with South America. The empty container management problem involves not only carriers, but also leasing companies, which possess more or less 50% of the world’s supply of containers and address the issue of deficiencies or excesses of containerized equipment. The reasons for their difficulty derive partly from the directional imbalance of trade traffic and partly from specific problems in this sector. The delivery of still larger ships to marine carriers, together with stagnation in trade, has given them an edge over leasing companies, since they can use the empty spaces on their ships to reallocate their own containers where there is a greater transportation demand. Moreover, in 2000 and the beginning of 2001, marine carriers ordered new containers, thus reducing the need to lease new boxes. What is more, carriers have a surplus of their own idle containers and, therefore, have diminished the demand for leasing services, which involves a massive reconsignment of containerized equipment to charterers.

The problem of idle equipment represents a serious burden for leasing companies because it not only does not produce any return, but daily involves unavoidable and exorbitant warehouse costs, thus engendering a negative flow of revenues. These costs vary depending on the location of deposits and, in the worse cases, can totally cancel the daily proceeds deriving from the leasing of another container of the same type. Another aspect is that leasing companies insist on having empty containers returned in favourable locations. Clauses to this effect are therefore included in contracts, even when they last for several years. In this situation, many leasing companies have destined large amounts of money in order to reposition empty containers from high cost “deposits-cemeteries”, situated near European and American ports, to less onerous storage areas in localities in China and other parts of Asia. Such localities offer far more favourable prospects for the chartering of equipment, especially after a market upturn.

Although transportation from North America to Asia can cost from 500 to 800 U.S.A. dollars per TEU, many tens of thousands of empty boxes were hauled by leasing companies on such routes during 2000, 2001 and 2002. Nowadays, the largest leasing companies currently spend something like 20-30 million U.S.A. dollars a year for the chartering of ships in order to perform such unprofitable empty movements (Source: Containerisation International Yearbook 2002).

Topics reported in this paper have shown that empty container management is a quite complex problem and the figures provided on this issue by several authors are alarming. For instance Crainic and al. (Crainic, Gendreau, Dejax; 1993) assert that 40% of all movements performed by major shipping companies operating in Europe are empty movements. It is therefore necessary to study and verify the feasibility of solutions which, by taking into account processes of production of demand, can lead to a substantial optimisation of the problem. However, the minimization of costs related to empty container management and the maximization of their use cannot be faced without further improving the quality of information regarding demand and supply. The partial lack of control and visibility of the largest carriers certainly means inefficient use of equipment and also involves lower levels of service provided to customers. Therefore it is desirable for a global operator to manage a closed network, where all transportation modes are under his monitoring activity. This appears to be an achievable objective because modern technology allows real-time visualization of the position and state of cargo and allows the adoption of an operating platform common to different intermodal partners.

More in general, the freight transportation market needs to promote cooperation between the several links of the logistic chain. Their trade alliances will allow transportation firms to better satisfy customers’ requests by resorting to partnership containers which would otherwise travel empty. The sharing by several companies of containers without logos (“grey containers”) is a development of this logic. Finally, since currently each forwarder requires at least one container, it is possible to deduce that in general load factors could be bettered.

3. Conclusions

In the context of intermodal freight transportation, empty container management is creating a significant logistic challenge for the transportation industry. This problem will never be eliminated completely, but only mitigated with efficient tools for solving problems connected with logistics and transport. The reduction of empty movements, besides improving the economic performance of the transportation system, will decrease traffic problems and its environmental impact with evident benefits for the quality of life.

At the moment the Department of Land Engineering of the University of Cagliari is conducting interesting research aimed at improving the management of empty containers. This problem, which belongs to the more general class of dynamic allocation of resources, can be faced effectively with the tools provided by Operation Research, which allow the minimization of costs related to the management of a generic empty cargo unit (trucks, cars in a railway system or containers). The approach of the methods used is
characteristic of the linear and not linear programming, with the aim of also considering the economies of scale deriving from the contemporary transport of numerous empty vehicles. Modelling frameworks characteristic reflect the operational complexity of the problem, particularly the space and time dependency of events, relationships with partner companies and massive equilibration flows. Interested readers may consult Crainic (Crainic and al., 1993), Cheung (Cheung and Chen, 1998), Holmberg (Holmberg and al., 1998), Joborn (Joborn and al. 2001), Choong (Choong and al., 2002).

The issue of dynamic allocation of resources problems also presents aspects of great concern for future research such as the simultaneous management of loaded and empty containers, the consideration of the effect of economy of scale on massive flows and the scenario formulation in a stochastic environment.

REFERENCES


Containerisation International Yearbook 2002.


