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AN ECONOMIC EVALUATION MODEL OF THE LOGISTIC SYSTEM BASED ON CONTAINER TRANSPORTATION

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Abstract. Over the recent years, the use of containers in the transport system has dramatically increased. The rise of world containerisation is the result of the interplay of macroeconomic, microeconomic and policy-oriented factors. World trade is facilitated through the elimination of trade barriers and the liberalisation and deregulation of markets. Market liberalisation revealed a demand for enhancing the development of logistics services throughout the world. In the conceptual metamorphosis of the transportation system, cargo movements are viewed in light of the total distribution system. Producers, commodity shippers, ocean, air and land carriers, ports, logistics managers, freight forwarders and consignees are involved in such a total system. The physical distribution of cargo, then, involves an integrated logistics system. This article examines of changes in the transport system that occurred during the last decades because of the invention and application of containers. Moreover, an economic model of evaluating the logistic system based on container transportation is discussed.

Keywords: containerization, intermodality, logistics, transport system.

1. Introduction

Containers came into the market for international conveyance of sea freight almost five decades ago. They may be regarded as well as accepted and continue to achieve even more acceptance due to the fact that containers are the foundation for a unit-load-concept. Containers are relatively uniform boxes the contents of which do not have to be unpacked at each point of transfer. They have been designed for easy and fast handling of freight (Muller 1995).

First regular sea container service began about 1961 with an international container service between the US East Coast and points in the Caribbean, Central and South America. The breakthrough after a slow start was achieved with large investments in specially designed ships, adapted seaport terminals with suitable equipment and the availability (purchase or leasing) of containers. A large number of container transhipments then led to economic efficiency and a rapidly growing market share. Today, over 60% of the world's deep-sea general cargo is transported in containers, whereas some routes, especially between economically strong and stable countries, are containerized up to 100%, see researches by Steenken *et al.* (2004).

The increasing number of container shipments causes higher demands on the seaport container terminals, container logistics and management as well as on technical equipment.

2. Development of the World Container Fleet

As of January 1st, 2006, the fully cellular container fleet stood at 3 514 ships with 111.6 mill dwt equal to 8.1 mill TEU total and the general cargo fleet comprised 16 544 ships with 97.4 mill dwt equal to 2.0 mill TEU (Fig. 1, 2). During the year 2005, the fully cellular container fleet grew by 13.5 percent (based on TEU). Compared with 1996, the fully cellular container fleet has more than doubled its TEU capacity (+203 per cent) whereby a disproportionate increase in the TEU capacity indicates the trend towards larger container ships.

Meanwhile, the first 9 178 TEU carriers with a capacity of 110 000 dwt are in service. The Swiss operator MSC employs these vessels in the Europe-Far East trade (ISL Shipping... 2006).

3. Trends Towards World Port Container Traffic

As presented in Shipping Statistics and Market Review, the total container traffic volume of the top container ports with container traffic of more than one mill TEU analysed here, reached 297 mill TEU in 2005 and

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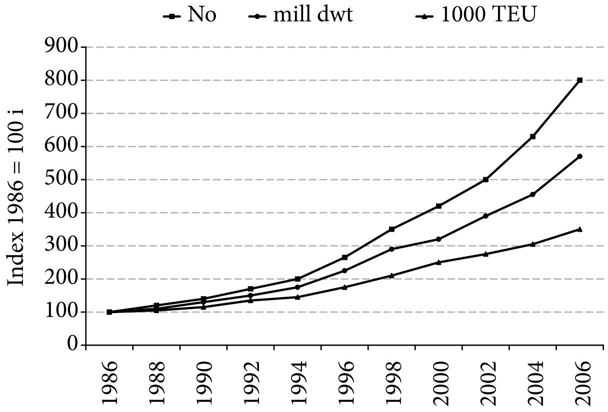

Fig. 1. Container fleet development as of January 1st, 1986–2006 (index 1986 = 100)

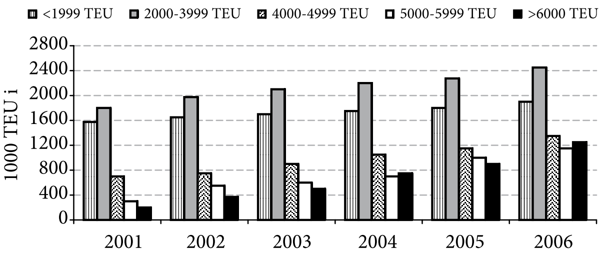

Fig. 2. Container fleet development by TEU-size classes as of January 1st, 2001–2006

increased by 10.9 per cent compared with the results achieved in 2004. In 2005, approximately 65 percent of the world container traffic, in terms of TEU, was attributed to Asian ports whereby the top 8 Chinese ports alone represented 26.5 percent of the total container traffic. Europe had a share of 18.5 and America 15.2 percent of the world container port traffic. The top Chinese mainland container ports (not including Hong Kong) grew on average by more than 25 percent yearly. Their annual container traffic summed up to 13.4 mill TEU in 1999 and 58.5 mill TEU in 2005 respectively.

The two leading Chinese Mainland ports, namely Shanghai and Shenzhen, 'only' showed the growth rates of less than 15 percent compared with the first quarters of 2005 and 2006. Shanghai and Shenzhen achieved the growth rates in the range between 20 and 30 percent up to 14.6 mill TEU and 13.5 mill TEU respectively in 2004. In 2005, these two ports handled 18 mill TEU and 15.9 mill TEU respectively. On a yearly basis, this is equal to an increase in 24.2 and 17.6 percent respectively. The growth of container transport in Chinese ports is also analyzed by Tolli and Laving (2007).

The major transhipment ports in the Near East are Dubai Ports, Khor Fakkan in the UAE, Salalah in Oman and Jeddah in Saudi Arabia.

All major container ports in the US showed substantial traffic gains. This is especially true for the West Coast ports of Long Beach, (plus 16.1 percent), Seattle (plus 17.4 percent), Tacoma (plus 14.8 percent) and Oakland (plus 11.1 percent).

In 2005, Rotterdam, the top European container port, increased its traffic by 12.3 percent. Rotterdam and Hamburg with a plus of 15.5 percent far above the average of the North Range Ports won market shares from Antwerp, Bremen/Bremerhaven and Le Havre. Le Havre's container traffic decreased again by 1.2 percent in the period of 2004/2005.

4. Impact of Containerization on the Transport System

The rise of world containerisation is the result of the interplay of macroeconomic, microeconomic and policy-oriented factors. World trade is facilitated through the elimination of trade barriers and the liberalisation and deregulation of markets (Noteboom 2004).

Since the late 1970s, and particularly in the latter part of the 1980s, international freight transport has embarked on a new cycle of innovations.

The new phase of transport development has been characterized not so much by technological innovations in ships, cranes or terminals as by alternations in the organization and synchronization of the transport industry.

The new trend that focuses on greater integration, cooperation and coordination of the various components of the transport system, is known as intermodal transportation (Leinbach and Capineri 2007).

Intermodality may be defined as the movement of cargo from shipper to consignee by at least two different modes of transport, under a single rate, with one bill of lading and single liability for the entire trip (Jaržemskienė 2007). The objective of intermodality is to transfer goods in a continuous flow through the entire transport chain from origin to final destination in the most cost- and time-effective way, see Lowe (2005). The concept of intermodality contrasts with the conventional segmented transport system in which each transport mode operates independently. The movement of goods in a single container by several modes of transportation has had a far-reaching impact on international and domestic trade as well as on the transport industry.

Greater efficiency and savings have been achieved by capitalizing on the relative advantages of various transport modes on every segment of the journey and through improved coordination of various transport segments (Lingaitienė 2008; Pocklad 2007; Kazakov 2006; Kolos 2006).

Containerization and the container units in particular, serve as the common denominator of a growing intermodal transport system (Slack 2001). If an intermodal container meets the weight limitations for ships, railcars, barges and container cranes but becomes 'overweight' when placed on a truck, it constrains the entire transport chain.

Containerization was introduced by the maritime transportation industry and has served primarily this industry. The inland transportation of international trade and the domestic transportation of commodities developed along two different avenues. With the advance of the intermodal concept during the 1980s, which was greatly enhanced by the deregulation of the transport industry, the focus of the transportation system gradually shifted from the seaside to the inland segments of the transport system. The relative importance of inland transportation to the total transport chain has been increasing as a direct result of the fact that the lion's share of the costs involved in door-to-door service on many international trade routes is related to the inland transport mode rather than to the ocean voyage. Consequently, the inland transport modes have started to challenge the dominance of the ocean carrier in the intermodal chain. The competitive position of the standard-size marine container has been decreasing in light of the higher volumes of common domestic containers, and the introduction of larger containers in the intermodal system is a clear indication of that trend.

Intermodal transportation may be interpreted differently and have different characteristics in a different parts of the world. These differences are greatly dependent on the geographical setting, the nature of the infrastructure and travel distances (Jaržemskis and Vasilis Vasiliauskas 2007).

However, the basic components and, certainly, the common denominator – the container – exist globally. This has become true particularly in the last decade when the importance of the world economy and the regional specialization of labour have rapidly grown.

5. Economic Indicators Describing the Performance of Logistic Systems Based on Container Transportation

Market liberalisation revealed a demand for enhancing the development of logistics throughout the world. International supply chains have become complex and logistics models evolve continuously as a result of influences and factors such as globalisation and expansion into new markets, mass customisation in response to product and market segmentation, lean manufacturing practices and associated shifts in costs. Customers' need for a wider array of global services and for truly integrated services and capabilities (design, build and operate) triggered integrated logistics strategies (Christopher 1992 and McKinnon 2001) and a shift from transportation-based 3PLs (third Party Logistics) to warehousing and distribution providers and at the same, opened the market to innovative forms of non-asset related logistics service provision, that is 4PL (Fourth Party Logistics).

In the conceptual metamorphosis of the transportation system, cargo movements are viewed in light of the total distribution system.

Producers, commodity shippers, ocean, air and land carriers, ports, logistical managers, freight forwarders and consignees are involved in such a total system. The physical distribution of cargo, then, involves an integrated logistics system the justification for an independent operation of a single mode of transportation in which has been weakening.

The efficiency and reliability of the entire transport system are determined by the weakest link in the transport chain. The relevance and effectiveness of seagoing vessels, trucks, railroads or ports are evaluated in relation to their roles as elements within a total system (Rushton *et al.* 2006).

The goals and results of the performance of a certain system are described by particular economic indicators that must reflect essentially the main planned tasks for the containerized system, which in turn assure reaching the global goal for the served logistic system, an actual degree of achieving the indicated tasks as well as the level of material and work costs necessary for the viability of the containerized transport system.

The main indicators of containerized system performance describing the planned task as well as the degree of achieving the global goal of the served logistic system are projected $Q_{pl}^{k}(T)$ and the actual $Q_{f}^{k}(T)$ amount of the containerized products (products moved in the containers) shifted over the agreed service time T.

If we imagine the whole system as a totality of subsystems P, then, in order to describe the plan of supplying containers and the actual degree of supplying containers for every particular subsystem, we use indicators $Q_{p}^{k}(T)$ and $Q_{p}(T)$.

Then, the indicators describing the total system will be expressed as follows:

$$Q_{pl}^{k}(T)=\sum_{p=1}^{P}Q_{p}(T),\ p=1,2,3,\ldots,P, \tag{1}$$

$$Q_{f}^{k}(T)=\sum_{p=1}^{P}Q_{p}(T),\ p=1,2,3,\ldots,P. \tag{2}$$

In order to identify the plan of use as well as a degree of using every particular type of container, indicators $Q_p(T)$ and $Q_p(T)$ are set as the sum of the agreed planned $Q_k(T)$ and actual $Q_k(T)$ amounts of the products moved by every single type of container K:

$$Q_{p}(T)=\sum_{k=1}^{k}Q_{k}(T),\ k=1,2,3,\ldots,K, \tag{3}$$

$$Q_{p}^{k}(T)=\sum_{k=1}^{k}Q_{k}(T),\ k=1,2,3,\ldots,K. \tag{4}$$

When taking into account expressions 1, 3 and 2, 4 we obtain that:

$$Q_{pl}^{k}(T)=\sum_{p=1}^{P}\sum_{k=1}^{K}Q_{k}(T), \tag{5}$$

$$Q_{f}^{k}(T)=\sum_{p=1}^{P}\sum_{k=1}^{K}Q_{k}(T). \tag{6}$$

Indicator $Q_{pl}^{k}(T)$ from formula 5 describes the planned amount of a product which is necessary in order to reach the global goal of the served logistic system. Indicator $Q_{f}^{k}(T)$ from formula 6 in turn shows the actual amount of a product which was dispatched to the customers.

A comparison of the above mentioned indicators will allow defining the degree of achieving the global goal of the served logistic system which depends on the performance of the containerized system. Therefore, we set a conditional indicator $\omega_Q(T)$ the percentage meaning of which shows the provision of the served system by the containerized products:

$$\omega_Q(T) = 100\frac{Q_f^k(T)}{Q_{pl}^k(T)} =$$
$$100\frac{\sum_{p=1}^{P} Q_p(T)}{\sum_{p=1}^{P} Q_p(T)} = 100\frac{\sum_{p=1}^{P}\sum_{k=1}^{K} Q_k(T)}{\sum_{p=1}^{P}\sum_{k=1}^{K} Q_k(T)}. \qquad (7)$$

Achieving the degree of the global goal that depends on the containerized system is described not only by the amount of products but also by the delivery of products on the 'right-on-time' base. In order to control the delivery of containers on the 'right-on-time' base, we need some indicators that would describe the planned and actual moments of delivery time of the loaded and empty containers. In this respect, the following indicators can be useful:

- $t'(T, P, K)$, $t''(T, P, K)$ – planned and actual time of delivering loaded (full) containers;
- $t'(T, P, K)$, $t''(T, P, K)$ – planned and actual time of delivering empty containers.

In order to evaluate how all functional processes taking part in the containerized system are performed on the 'right-on-time' basis, we shall use indicator $P_t(T)$:

$$P_t(T) = 1 - \sigma, \qquad (8)$$

where: $P_t(T)$ – the reliability of the functional processes performed on the 'right-on-time' basis; $\sigma(T)$ – a part of containers that failed to be delivered on the 'right-on-time' basis.

$$\delta(T) = \frac{P_{np}}{N_n}, \qquad (9)$$

where: $P_{np}(T)$ – the number of containers that failed to be delivered on the 'right-on-time' basis; $N_n(T)$ – a total number of containers being transported in a certain system.

In order to assure the economic viability of the given containerized system, loaded and empty containers must be delivered with the possibly minimum, total material and work (labour) costs (expenditures).

The above mentioned requirement can be reflected with the help of the following indicators:

$$Z_{pl}(T) = \frac{P_{pl}(T)}{Q_{pl}^k(T)}; \qquad (10)$$

$$Z_f(T) = \frac{P_f(T)}{Q_f^k(T)}, \qquad (11)$$

where: $Z_{pl}(T)$ and $Z_f(T)$ – a planned and actual comparative indicator of costs that can be associated with a single unit of a product transported in the container respectively; P_{pl} and P_f – the planned and actual costs of delivering the whole amount of a product.

In order to evaluate the degree of achieving the economic reliability of the functional processes taking place in a given containerized system, we introduce a conditional indicator, the percentage meaning of which shows the actual comparative costs of loaded and empty container transportation:

$$\omega_z(T) = 100\frac{Z_f(T)}{Z_f(T)}. \qquad (12)$$

However, all these indicators very often can not describe the planned and actual amount of work done by the containerized system. This is due to the fact that often containers are not moved directly from shipper to customer but rather through the set of the intermediate places where various technological operations are performed. Taking this into account, actual work performed in the container system can be evaluated by the following indicators:

- $K_{pl.p}$ – the planned ratio of additional work equal to the proportion between the planned to transport amount of product $\tilde{Q}_{pl}^k(T)$ (taking into account all necessary additional operations to perform product transportation) and the amount of product $Q_{pl}^k(T)$ delivered to the final consumer:

$$K_{pl.p} = \frac{\tilde{Q}_{pl}^k(T)}{Q_{pl}^k(T)}; \qquad (13)$$

- $K_{f.p}$ – the actual ratio of additional work which is the proportion between the actual amount of the transported product $\tilde{Q}_f^k(T)$ (taking into account all really performed operations) and the actual amount of product $Q_f^k(T)$ delivered to the final user.

$$K_{f.p} = \frac{\tilde{Q}_f^k(T)}{Q_f^k(T)}. \qquad (14)$$

Ratios $K_{f.p}$ and $K_{pl.p}$ can be different not only when $Q_{pl}^k \neq Q_f^k$, but also because redundant additional operations are sometimes performed.

A comparison of the above mentioned ratios allows to create a conditional indicator $\omega_k(T)$ the percentage meaning of which shows the actual redundant amount of work performed by the containerized system.

$$\omega_k(T) = 100\frac{K_{f.p}}{K_{pl.p}}. \qquad (15)$$

Considering that sometimes $Q_{pl}^k(T) \leq \tilde{Q}_{pl}^k(T)$ and $Q_f^k(T) \leq \tilde{Q}_f^k(T)$ is not a surprise that the total material and labour costs necessary for the existence of the containerized system can exceed meanings $Z_{pl}(T)$ and $Z_f(T)$.

In such case, the conditional planed $\tilde{Z}_{pl}(T)$ and actual $\tilde{Z}_f(T)$ indicators of costs associated to one labour unit of the containerized system can be calculated as follows:

$$\tilde{Z}_{pl}(T) = \frac{\tilde{P}_{pl}(T)}{\tilde{Q}^k_{pl}(T)}; \quad (16)$$

$$\tilde{Z}_f(T) = \frac{\tilde{P}_f(T)}{\tilde{Q}^k_f(T)}, \quad (17)$$

where: $\tilde{P}_{pl}(T)$ and $\tilde{P}_f(T)$ – the planned and actual costs necessary for the existence of the containerized system (also taking into account the planned and actual set of operations necessary for product delivery).

6. Conclusions

1. The rise of world containerisation is the result of the interplay of macroeconomic, microeconomic and policy-oriented factors. World trade is facilitated through the elimination of trade barriers and the liberalisation and deregulation of markets.
2. The increasing number of container shipments causes higher demands for the seaport container terminals, container logistics and management as well as for technical equipment.
3. The movement of goods in a single container by several modes of transportation has had a far-reaching impact on international and domestic trade as well as on the transport industry.
4. Market liberalisation revealed a demand for enhancing the development of logistics throughout the world. International supply chains have become complex and logistics models evolve continuously as a result of influences and factors such as globalisation and expansion into new markets, mass customisation in response to product and market segmentation, lean manufacturing practices and associated shifts in costs.
5. In the conceptual metamorphosis of the transportation system, cargo movements are viewed in light of the total distribution system. Producers, commodity shippers, ocean, air and land carriers, ports, logistical managers, freight forwarders and consignees are involved in such a total system. The physical distribution of cargo, then, involves an integrated logistics system the justification for an independent operation of a single mode of transportation in which has been weakening.
6. The goals and results of the performance of a certain system are described by particular economic indicators that must reflect essentially the main planned tasks for the containerized system, which in turn assure reaching the global goal for the served logistic system, an actual degree of achieving the indicated tasks as well as the level of material and work costs necessary for the viability of the containerized transport system.

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