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Foldable Containers to Reduce the Costs of Empty Transport? A Cost–Benefit Analysis from a Chain and Multi-Actor Perspective

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Transport of empty containers, which arises from the need to reposition containers, is an expensive business. This holds in particular for shipping lines, which are usually responsible for container repositioning and have to bear these container management costs. Shipping lines are known to follow various strategies to reduce the costs of empty transport. A rather unfamiliar, but interesting option to save costs is the possibility to fold empty containers. This could save transport costs, but also transhipment and storage costs. In this paper, we analyse the opportunities for commercial application of foldable containers. For this purpose a cost–benefit analysis is adopted in which four logistic concepts to use foldable containers are presented as a framework for analysis. The costs and benefits of using foldable containers in these logistic concepts are calculated and compared with the situation in which standard containers are used. It is shown that the use of foldable containers can lead to substantial net benefits in the total chain of container transport. However, much depends on the additional costs that foldable containers cause, that is, the cost of folding and unfolding, additional exploitation costs and any additional transport to places where folding and unfolding can take place. The logistic concept plays a part in it, but it should be a great challenge for designers and container producers to develop a foldable container that generates limited additional costs.
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INTRODUCTION

The arrival of the maritime container in the middle of the 1960s led to a great improvement of freight transport in many respects. The transfer of goods became much easier and safer and the use of containers paved the way for intermodal transport development. At present, the maritime container dominates the shipping industry and the extent of its influence in land transport is also substantial.

An important downside of containerisation however is that the place where containers are loaded and unloaded is often not the same, so transport movements of empty containers are unavoidable. On a global level, imbalances in container trades are a familiar and persistent problem. Large numbers of empty containers are being moved around the world. Drewry Shipping Consultants estimate the share of empty containers at sea as 21% of all containers transported. For land transport the estimates are even higher (about 40%). These unproductive movements involve high costs. Total costs to the industry of this inefficiency amounted to 10 billion dollars in 2003. These are the costs of interzonal positioning (ie movements including a significant sea voyage). Including intrazonal positioning (ie movements overland) would add another 5 billion dollars.

Of course container transport imbalances have always existed, but recent developments have brought the issue to the fore. First of all there was the Asian financial crisis in 1998. This caused a demand fallout and severe imbalances on the major East/West trade routes and it took a long time before these imbalances more or less returned to normal. Imbalances are rapidly increasing again, due to a robust growth of containerised trade within Asia and fuelled mainly by exports from China. As a result, trade volumes to and from Asia are significantly imbalanced and volumes of empty containers bound for Asia are swiftly growing (see Figure 1). Moreover, based on economic forecasts, it is likely that this pattern will last for quite some time. In view of the strong competition among shipping lines and the role of efficient container fleet management as a key factor in cutting operating costs, the issue of repositioning empty containers is again gaining importance.

In reviewing the present strategies of shipping lines to control the costs of empty transport (see Konings and Thijs, 2001), one can notice that these strategies are mainly focused on minimising transport movements of empty containers. This is done by trying to improve the match of empty containers and cargo. Reliable and up-to-date information about the location of containers and cargo are crucial conditions and sophisticated information and communication systems have proved to be very useful for that. However, these strategies do not influence the actual costs of empty containers. From this perspective the

Figure 1: Container transport volumes in major trade routes (million TEU), 2003

foldable container could be an interesting addition to the current strategies, particularly knowing that empty transport can never be eliminated completely, even with perfect information systems.

In this paper, the opportunities for commercial application of foldable containers are examined. This is done on the basis of a cost–benefit analysis, in which the effects on a chain level as well as for the individual actors in the logistic chain are considered.

The costs and benefits of foldable containers will depend to a large extent on the way they are used. The following section presents four basic logistic concepts to use foldable containers. These concepts form the framework for the cost–benefit analysis. Based on the cost structure of container transport the different cost elements of a logistic chain are discussed. Then these costs are quantified for a reference situation in which standard containers are used. Next the costs and benefits of foldable containers for the different logistic concepts are compared to this reference situation. Here, the cost effectiveness of foldable containers is evaluated within a total chain. However, since various actors are involved in the logistic chain, costs and benefits might accrue to different actors. This could form a barrier to the market introduction of foldable containers. Therefore, it is relevant to know the specific interests of the different actors and their possible role in introducing foldable containers. This is discussed in the next section. After this discussion, we finally try to explain the current gap between theory and practice of foldable containers, because although foldable containers seem promising, they are not widely used yet. A brief overview of the experiences with foldable containers so far may shed light

on this issue. The paper ends with an outlook on the viability of foldable containers.

BASIC LOGISTIC CONCEPTS FOR THE APPLICATION OF FOLDABLE CONTAINERS

In theory containers could be folded anywhere in the logistic chain if they are empty and if there is a rationale to do so. However, in general the distance to move empty containers and the type of movement, that is, transportation at sea or land, will play an important role. In view of these general notions and in order to structure the analysis, it is useful to define some basic logistic concepts which could be applied to foldable containers.

Based on the number of links in the logistic chain in which containers are used in folded state, we distinguish the following basic logistic concepts (see also Figure 2).

I. *Port-to-port concept*
- One sea trade lane: point to point transport.
- Long distances.
- Over sea (deep sea).
- Transport of folded containers between two seaports (container depots).

II. *Maritime world-wide concept*
- Repositioning between continents: trunk routes, coarse-grained network.
- Long distances.
- Over sea (deep sea).
- Transport of folded containers between seaports (container depots).

III. *Maritime/continental world-wide concept*
- Repositioning within and between continents: coarse-grained network.
- Long and medium length distances.
- Over sea (deep sea + short sea) and/or overland.
- Transport of folded containers between seaports, between seaports and container depots in the hinterland and between container depots in the hinterland.

IV. *Door-to-door world-wide concept*
- Transport between and within continents: fine-meshed network.
- Long and medium length distances.
- Overland and over sea.
- Transport of folded containers between customers and container depots in the hinterland, between container depots and seaports and between seaports.

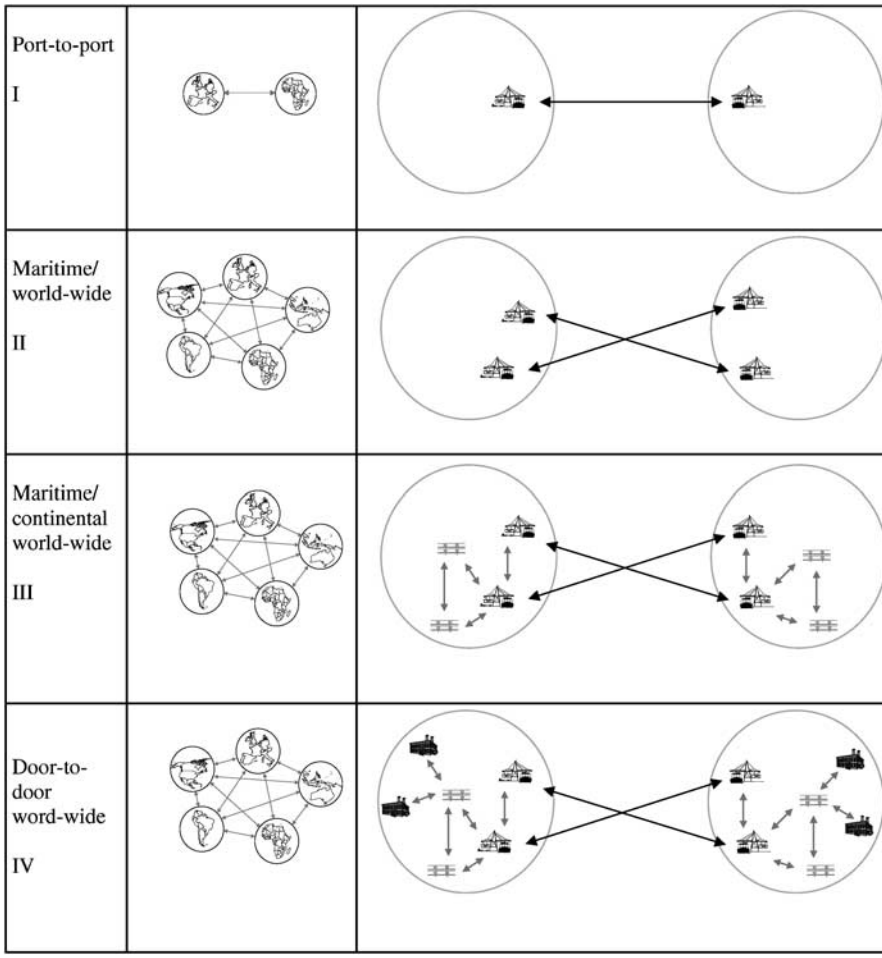

Figure 2: Logistic concepts for the application of foldable containers

The simplest concept is the port-to-port concept (I). Such a concept would be implemented for client-specific solutions for a specific trade lane. Trades with a permanent imbalance would make up the most important area of application. The foldable container ensures a more efficient return journey for the container. The containers are predominantly used on one and the same route (point to point transport), so that certain expertise can be built up in the folding and unfolding of containers. Owing to fine-meshed and relative small return flows to the shipment port, the seaport is the most suitable and likely location for joining together the empty containers (a port-to-port concept). In

other words, containers are transported in folded state only at sea in this concept. The application field has the character of a niche market; the transport volumes are modest. The character of the trades is such that the container is most likely used for a restricted category of products only. The number of parties involved in the logistic chain of the foldable container can be quite small (eg one shipping company, two terminals, two seaport depots).

The maritime/worldwide concept (II) assumes repositioning of empty containers between continents. Here, containers are also folded at the sea journey only. However, repositioning foldable containers on a global scale assumes that a relatively large number of units are available and, consequently, these containers can be used to transport many kinds of products. Nevertheless, the number of different parties involved in the logistic chain of the foldable container may still be quite small (eg shipping companies, terminals, seaport depots). The actual number of involved parties depends on the number of shipping companies using foldable containers and the number of ports to be called.

The maritime/continental – worldwide concept (III) is one where further optimisation of repositioning is contemplated, because the movement of empty containers within continents, that is, over land, is also included. Consequently, the number of different parties involved in the logistic chain of the foldable container becomes large (eg shipping companies, terminals, seaport depots, inland operators and inland depots). Such a concept also assumes that a large number of containers will be used (large transport volumes) and that containers are suitable to transport many types of products.

The door-to-door-concept (IV) assumes that, wherever convenient, empty containers will be transported in folded state. The containers can be assembled and disassembled anywhere and they can therefore be used world-wide. The number of containers in this concept need not necessarily be large, any more than the requirement of suitability for many types of products has to be met. However, the number of different parties involved in the logistic chain is relatively large (eg shipping companies, terminals, seaport depots, inland operators, inland depots and shippers/receivers of goods).

In the concepts I, II and III, it is likely that scale advantages can be achieved in folding and unfolding containers, because these activities are concentrated at depots.

COST STRUCTURE OF CONTAINER TRANSPORT

Two sorts of costs in container transport can be distinguished: container costs and movement costs.

Container costs

Container costs are the costs associated with the purchase and use of the container, that is to say the exploitation costs. These costs consist of a fixed part (capital and depreciation) and a variable part (maintenance and repair, insurance, cleaning and inspection).

The purchase price of a new container and its depreciation term largely determine the fixed costs. A container lasts from 10 to 15 years, depending on the type of cargo, the trade lane and the intensity of use. These factors are also relevant for the variable costs, in particular maintenance and repair.

Since fixed costs have a large share in total costs, the purchase price of a container is of particular importance for the exploitation costs. Prices of new containers decreased dramatically since the mid-1990s. The price of a 20 ft standard box dropped from US$ 2,400 in 1995 to US$ 1,500 in 2000. From that time on prices remained fairly stable at this low level, but high steel costs and a strong demand for new containers have boosted the price up again in 2004 to US$ 1,900 (Foxcroft, 2004b).

For the analysis in this paper, total container costs have been estimated using lease rates as a basis. Container costs have thus been set at US$ 1 per day for a 20 ft container, although the long-term daily lease rate was US$ 0.85 in 2004, a rate level that was also much higher than in previous years (Foxcroft, 2004a). However, since a lease rate reflects a market price including a profit margin for the lessor company, a rate of US$ 1 per day could be considered as the upper limit of the container costs.

Movement costs

Movement costs are those that derive from the transport of the container and related activities such as transhipment and storage. In other words, these costs are associated with container logistics. According to the possible activities of a container in a logistic chain in maritime transport (see Figure 3), the following cost items can be distinguished:

Depot storage/terminal storage (storage place) (actions 18 and 10 in Figure 3)
Containers for which there is temporarily no cargo available are stored for a shorter or longer time. This can occur at a terminal (seaport or inland terminal)

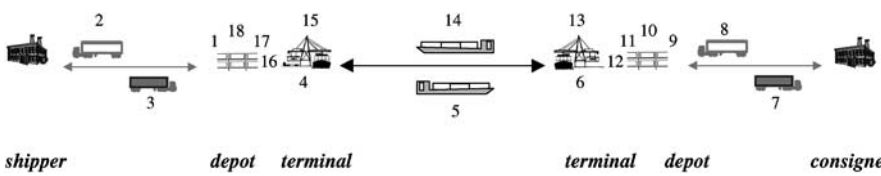

Figure 3: Representation of a typical logistic chain in maritime container transport

or at a depot (in the seaport or the hinterland). The choice between depot or terminal depends in part on the turnaround rate of the containers: the shorter the turnaround time the stronger the preference for temporary storage at a terminal. This consideration is only relevant to carriers. Leasing companies are almost always dependent on depots. In the longer-term case, storage in a depot can be more advantageous. In this choice, the opportunities of ocean carriers to claim 'cheap' storage, or to have their own storage facilities at a terminal, also play a part. A disadvantage of depot storage is that extra transport may be necessary (between terminal and depot). The maximum tariff that depot owners charge for storage is about US$ 1 per container per day. The tariff depends on the duration of storage and the type of client.

Depot discharge (actions 1 and 11 in Figure 3) and depot receipt (actions 9 and 17 in Figure 3)
An empty container needs to be moved from the depot onto a chassis (actions 1 and 11) and from a chassis into the depot (actions 9 and 17) when it is returned. Receipt and discharge tariffs partly depend on the number and turnaround rate of containers. The turnaround rate for containers of leasing companies is usually lower than for shipping companies, so that the tariffs for leasing companies are usually somewhat higher. Tariffs for such handlings vary between US$ 8 and US$ 15.

Transport between terminal and depot (actions 12 and 16 in Figure 3)
Whenever a container is stored in a depot, additional transport between terminal and depot may be necessary. These transport costs are determined by transport distance. Since depots form a back up facility of terminals, they are usually located nearby terminals in the seaport and often at the site of terminals in the hinterland. Therefore, these transport costs are usually modest.

Costs of inland transport: shipper – port (actions 2 and 3 in Figure 3) and port – consignee (actions 7 and 8 in Figure 3)
Inland transport costs consist of transporting the container from the storage place (depot or terminal) to the shipper and from the shipper to the sea terminal (actions 2 and 3). In addition, there are costs for transporting the container from the sea terminal to the consignee and from the consignee to the container storage place (depot or terminal) (actions 7 and 8). The costs of these land side transportations depend on:

- The transport distance between the shipper/consignee in the hinterland and the port;
- The modal choice (road, rail, or inland waterway transport);

- The collection or return address of the empty container. If the container can be collected or delivered at a local depot, this will save costs: empty transport over long distances is avoided.

To estimate the inland transport costs, data for road transport of containers exist and are rather reliable. In Europe, calculations for long-distance transport (more than 300 km) are in daily practice, often based on a cost per kilometre. These costs are about US$ 0.7 per km for a single journey distance. That is to say, the cost of a back and forth journey to an inland destination located at 500 km is about US$ 700.

Container handling charges in the port (actions 4, 6, 13 and 15 in Figure 3)
The container handling charges cover the costs of the transfer of inland transport modes to the ship (or *vice versa*). Although the handling equipment used at seaport terminals is rather uniform, container handling tariffs differ considerably between ports and terminals. Tariffs charged to shipping companies may even vary at one and the same terminal and they are subject to strong negotiation. The tariffs include a cost-free stacking time at the terminal (temporary storage), which may also vary considerably. Moreover, these tariffs and cost-free periods are often also different for full and empty containers. In general, the tariff structure is not transparent. Much depends on the negotiating strength of shipping lines. Based on data for the European container port industry, these container handling charges range form US$ 90 to US$ 150.

Transport costs for the sea leg of a journey (actions 5 and 14 in Figure 3)
Sea transport costs mainly consist of sailing costs, which are the total of various cost elements. For the cost calculation in this paper, the total slot costs per Twenty foot Equivalent Unit (TEU) are particularly relevant. These slot costs are strongly related to the size of the ship and are approximately as follows (Van Slobbe, 2000):

- 1,000 TEU ship: US$ 20 per TEU per day.
- 3,000 TEU ship: US$ 13 per TEU per day.
- 7,000 TEU ship: US$ 10 per TEU per day.

(These slot costs include voyage costs such as bunkers and port fees).

To what extent such costs should be the ones assigned to the transport of empty containers, is more or less a theoretical issue (Blauwens *et al*, 1996; Rietveld, 1998). When the ship is only partly filled with revenue containers, the marginal cost of transporting empty containers is small. The ship has to sail

anyway and empty containers merely use spare capacity. However, this is a short-term view and only from the perspective of the carrier. In the long run all costs must be covered. From this perspective, the costs of empty transport could be considered as opportunity costs for the unproductive use of slots. From the perspective of forwarders, shippers, leasing companies as well as ocean carriers who have to charter capacity from other carriers, the situation is however different. Since they are charged market tariffs, they are confronted with much higher costs.

Reference situation: Costs of using standard containers

In order to compare the cost performance of foldable containers with standard containers, a case study is elaborated. In this case study, first of all a representative chain for maritime container transport is described. For this chain, the costs of using standard containers are determined as a reference situation. Next, these calculations are compared with the costs which result from using foldable containers.

Based on information provided by companies from the container industry, the following general assumptions are made about the chain structure and the cost levels:

- There is an imbalance in cargo flows so that empty containers have to be repositioned over sea (deep sea).
- The shipping company is responsible for the repositioning of empty containers.
- Duration of sea leg: 20 days (single journey).
- Duration of land leg: 20 days (total of both land sides and the stay at terminals and in depots is included).
- Container depots in ports are situated in the direct vicinity of the terminals.
- The distance between shipper and port of origin: 400 km.
- The distance between port of destination and consignee: 400 km.
- Inland transport costs are based on road transport: US$ 0.70 per km.
- Exploitation costs per container: US$ 1 per day.
- Container handling charges: US$ 100.
- Tariff for depot receipt or discharge: US$ 10 per container.
- Tariff for depot storage: US$ 0.50 per day.
- Average duration of an empty container in the depot in one chain cycle: 10 days.
- Containerships are of average size; slot costs per TEU: US$ 15 per day.
- Overhead costs (administration and so forth) of sea transport: US$ 50 per container.
- There are no additional costs for storage at the terminal.

Table 1: Chain costs for the transport of a standard 20 ft container: reference situation

Activities	US$	Percent
Movement costs:		
1 Depot discharge	10	0.4
2 Transport port–shipper (empty)	275	11.9
3 Transport shipper–port (full)	275	11.9
4 Container handling cost (full)	100	4.3
5 Sea transport (full)	350	15.2
6 Container handling cost (full)	100	4.3
7 Transport port–consignee (full)	275	11.9
8 Transport consignee–port (empty)	275	11.9
13 Container handling cost (empty)	100	4.3
14 Sea transport (empty)	350	15.2
15 Container handling cost (empty)	100	4.3
16 Transport terminal–depot	25	1.1
17 Depot receipt	10	0.4
18 Depot storage (empty)	5	0.2
Container costs:		
Exploitation costs	60	2.6
Total	2310	100.0

In addition, some supplementary assumptions are necessary about the role of the terminal *versus* the depot as a place for temporary storage of empty containers. It is assumed that in a country where there is a cargo deficit, empty containers will not be stored in a depot, but will immediately be made ready for reshipment. The activities 9, 10 and 11 remain outside the chain. In a country where there is a cargo surplus, containers are temporarily stored in the depot, awaiting a new shipping order (activities 17, 18 and 1).

Such a chain process takes up a middle position with respect to costs. The most favourable scenario is the situation where the depots are not used at all. The most unfavourable scenario is the situation where depots are used on both sides of the chain. In Table 1, the total chain costs, split up by activities, are shown. From Table 1, three important conclusions can be drawn:

- The share of the exploitation costs of the container in the total chain costs is marginal ($<3\%$).
- The costs of container storage are negligible compared to other chain costs ($<1\%$).
- The inland costs are relatively high in the total chain costs (about 50%).

COSTS AND BENEFITS IN THE USE OF FOLDABLE CONTAINERS

The use of foldable containers leads to some additional costs in the logistic chain, namely:

- Costs of folding and unfolding (manpower plus ancillary equipment), in relation to the number of times that a container is folded and unfolded in the logistic chain;
- Higher exploitation costs for a container, because of a higher purchase price and probably higher maintenance and repair costs due to a more complex construction.

These additional costs are dependent on the design of the container. Moreover, there is a certain trade-off between these costs, but because of this dependency on design, these costs are difficult to estimate. However, the financial margins for these extra costs can be calculated.

These margins should arise from cost savings (benefits) somewhere else in the logistic chain in order to make foldable containers an attractive alternative. Opportunities for cost savings are found in the following activities in the logistic chain:

- Storage: if empty containers can be stored in folded state at a terminal or in a depot, less space is needed; terminal and depot storage costs per unit can be reduced and terminals operated more efficiently;
- Transhipment: if folded empty containers can be bundled and handled together, terminal transhipment costs per unit can be reduced;
- Transport: if folded empty containers can be bundled and transported together, less transport capacity is needed and transport costs per unit can be reduced.

What net benefits a foldable container produces and who enjoys these benefits depends on where in the logistic chain foldable containers are used in folded state, or in other words, which logistic concept is being used. The costs and benefits have been calculated on the basis of the logistic concepts presented earlier. For meaningful comparison of the various concepts, the chain processes have been assumed to be the same. In other words, the point of departure in the chain is invariably the container storage place in the port.

Logistic concept I: Port-to-port

Characteristic of the port-to-port concept is that empty containers are only transported at sea in folded state. Folding and bundling of empty containers takes place in depots in the seaport.

With regard to the use of foldable containers, the following specific assumptions are made:

- Five empty foldable containers can be bundled into a unit, the size of one standard container.
- Receipt and discharge of a package of folded containers puts greater demands on the equipment at the depot and requires more supervisory activities (eg inspection); moves at the depot become relatively more expensive (11, 17).
- Inspection activities with respect to incoming or outgoing unfolded containers belong to the process of folding and unfolding (9a, 1a); there is therefore no reason to suppose that the costs of depot discharge (1) or depot receipt (9) would change.
- Although the costs, for the shipping company, of transporting empty containers at sea are often assumed to be close to zero, a correct assignment of sea transport costs requires the inclusion of the slot costs per TEU: US$ 60 ($=15$ $/slot day * 20 days/5).
- Overhead costs for sea transport (administration and so forth) remain the same for folded and standard containers (US$ 50).
- Insofar as the costs of depot storage (18) are exclusively determined by the space taken up, the storage costs for empty containers then decline by a factor of five.
- Terminal handling charges for a package of folded containers are the same as for one standard container.

The potential chain savings in this concept amount to US$ 420 and are built up as follows (Table 2):

- Sea transport: US$ 240 (opportunity cost for a shipping company).
- Container handling charges: US$ 160 ($2 \times$ US$ 80).
- Transport from terminal to depot: US$ 20.

These benefits of US$ 420 should be large enough to cover the following additional costs:

- The costs of folding a container (plus the associated inspection costs and so forth) (F).
- The costs of unfolding a container (plus the associated inspection costs and so forth) (F).
- The additional exploitation costs of a foldable container (on the basis of 60 days' use) (E).
- The costs of any transport between depot and terminal in the surplus area (T).

Table 2: Chain costs for the transport of a foldable 20 ft container according to the port-to-port concept

Activities	Port-to-port (US$)	Reference (US$)
Movement costs:		
1a Unfold container	F	
1 Depot discharge *(as a standard container)*	10	10
2 Transport port–shipper (empty)	275	275
3 Transport shipper–port (full)	275	275
4 Container handling cost (full)	100	100
5 Sea transport (full)	350	350
6 Container handling cost (full)	100	100
7 Transport port–consignee (full)	275	275
8 Transport consignee–port (empty)	275	275
9 Depot receipt *(as a standard container)*	10	
9a Fold container	F	
11 Depot discharge	>2	
12 Transport depot–terminal	T	
13 Container handling cost (empty)	20	100
14 Sea transport (empty)	110	350
15 Container handling cost (empty)	20	100
16 Transport terminal–depot	5	25
17 Depot receipt	>2	10
18 Storage (empty)	1	5
Container costs:		
Exploitation costs	60+E	60
Total	1,890+2F+E+T	2,310

Logistic concept II: Maritime – worldwide

The main idea in this concept, as in concept I, is that containers are only transported in the folded state at sea, even though the sea leg is not restricted here to one corridor (port–port) but many sea routes are involved (worldwide). In terms of chain savings, there are no real differences from concept I. The sea journey distance (sea journey time) is an important variable in the evaluation of routes on which the concept of foldable containers may or may not be cost-effective.

Logistic concept III: Maritime/continental – worldwide

In this concept, containers are transported in folded state at sea and also overland. Containers are folded and unfolded in depots in the hinterland. An additional assumption is that the distance between a customer and a local depot in the hinterland is on average 75 km. Bearing in mind that the return of an empty container to a depot after it is unloaded at the consignee is a subsidiary activity that is a part of the transport from port to hinterland, the

costs of this transport movement are calculated the same way. These costs are about US$ 50.

The potential chain savings amount to US$ 590 and are built up as follows (Table 3):

- Sea transport: US$ 240 (opportunity cost for a shipping company).
- Container handling charges: US$ 160 ($2 \times$ US$ 80).
- Land transport: US$ 170 ($=220–50$ for transport from consignee to depot).
- Transport from terminal to depot: US$ 20.

These benefits of US$ 590 should be large enough to cover the following additional costs:

- Transport from consignee to local depot where the container is folded: US$ 50 (in this example calculation).
- The costs of folding a container (plus the associated inspection costs and so forth) (F).

Table 3: Chain costs of the transport of a foldable 20 ft container according to the maritime/continental–worldwide concept

Activities	Maritime/contin. Worldwide (US$)	Reference (US$)
Movement costs:		
1a Unfold container	F	
1 Depot discharge *(as a standard container)*	10	10
2 Transport port–shipper (empty)	275	275
3 Transport shipper–port (full)	275	275
4 Container handling cost (full)	100	100
5 Sea transport (full)	350	350
6 Container handling cost (full)	100	100
7 Transport port–consignee (full)	275	275
8a Transport consignee–local depot *(empty; as a standard container)*	50	
9 Depot receipt *(as a standard container)*	10	
9a Fold container	F	
11 Depot discharge	>2	
8b Transport depot–port (bundle of empty containers)	55	275
13 Container handling cost (empty)	20	100
14 Sea transport (empty)	110	350
15 Container handling cost (empty)	20	100
16 Transport terminal–depot	5	25
17 Depot receipt	>2	10
18 Storage (empty)	1	5
Container costs:		
Exploitation costs	60+E	60
Total	1,720+2F+E	2,310

- The costs of unfolding a container (plus the associated inspection costs and so forth) (F).
- Additional exploitation costs of a foldable container (on the basis of 60 days' use) (E).

Logistic concept IV: Door-to-door

Characteristic of this concept is that empty containers in the folded state are transported to the door of the shipper and/or consignee. The number of links in the chain in which the containers are folded is therefore large.

Additionally the following assumptions are made:

- Empty containers are stored in folded state by the client until a sufficient quantity of empty containers is available for bundled transport to the port.
- As a result of temporary storage of empty containers at the premises of clients, the turnaround rate of the containers will be lower than in case of bundling containers at a local depot. This is a result of the law of large numbers. Therefore, the chain cycle becomes longer and as a result, the container exploitation costs per cycle increase. These costs are indicated by X.
- Containers, which are temporarily stored by the customer, require space. These costs for storage are indicated by S.

The potential chain savings amount to about US$ 650 and are built up as follows (Table 4):

- Sea transport: US$ 240 (opportunity cost for a shipping company).
- Container handling charges: US$ 160 ($2 \times$ US$ 80).
- Land transport: US$ 220.
- Transport form terminal to depot: US$ 20.

The benefits of US$ 650 should be large enough to cover the following additional costs:

- The costs of folding a container (plus the associated inspection costs and so forth) (F).
- The costs of unfolding a container (plus the associated inspection costs and so forth) (F).
- The additional exploitation costs of a foldable container (on the basis of 60+ days' use) (E+X).
- The costs of storage with the customer (S).

In concepts III and IV, the potential benefits in land transport depend to a large extent on the organisation of transport. It should be possible to uncouple the outward and return trips of the transport vehicles. Otherwise there is still expensive, unproductive transport of empty tractors and trailers. In

Table 4: Chain costs of the transport of a foldable 20 ft container according to the door-to-door concept

Activities	Door-to-door (US$)	Reference (US$)
Movement costs:		
1a Unfold container	F	
1 Depot discharge *(as a standard container)*	10	10
2 Transport port–shipper (empty)	275	275
3 Transport shipper–port (full)	275	275
4 Container handling cost (full)	100	100
5 Sea transport (full)	350	350
6 Container handling cost (full)	100	100
7 Transport port–consignee (full)	275	275
7a Fold container	F	
7b Storage with consignee	S	
8 Transport consignee–port (bundle of empty containers)	55	275
13 Container handling cost (empty)	20	100
14 Sea transport(empty)	110	350
15 Container handling cost (empty)	20	100
16 Transport terminal–depot	5	25
17 Depot receipt	>2	10
18 Storage (empty)	1	5
Container costs:		
Exploitation costs	60+E+X	60
Total	1,658+2F+E+X+S	2,310

this respect intermodal transport offers a number of advantages over unimodal road transport. Moreover, in both concepts, extra cost savings are possible if empty containers can also be folded on the land leg between seaport and shipper.

Financial margins in the use of foldable containers

The above analyses show that very different variables influence the economic viability of foldable containers. To some extent the costs that have been assumed are situation specific. The costs of folding and unfolding, the exploitation costs of the container, costs of supplementary transport to locations where containers can be folded and unfolded and the turnaround rate of the container (the container productivity) are all important. The effects of changes in these variables on economic viability have been tested by means of sensitivity analysis, which has been carried out for the port-to-port concept. This concept provides the most conservative estimation of benefits. Table 5 shows how much folding and unfolding may cost, for chain costs to equal the costs of using standard containers, for various circumstances regarding the

Table 5: Break-even costs (in US dollars) for folding and unfolding a container for different purchase prices; turnaround rates (# cycles/year); and costs of transport from depot to terminal (port-to-port concept)

Purchase price (US$)	4000			5000			6000		
Number of transport cycles/year	**4**	**6**	**8**	**4**	**6**	**8**	**4**	**6**	**8**
Transport costs depot–terminal (US$)									
0[a]	177	258	298	115	217	268	95	177	238
50	127	208	248	65	167	218	45	127	188
75	102	183	223	40	142	193	20	102	163
125	52	133	173	Loss	92	143	Loss	52	113

[a]Container depot is located at the site of the seaport terminal.

exploitation costs of the container (assumed to be a linear function of its purchase price); the turnaround rate of the container; and the cost level of supplementary transport to locations where containers can be folded and unfolded. For example, let us assume that the purchase price of a foldable container is $ 6,000 (based on information from the container industry), the container can make six transport cycles a year and that folding and unfolding can take place at the site of the seaport terminal. Under these conditions, folding and unfolding the container (including complementary depot activities) should cost $ 177 per roundtrip, in order to have equal chain costs of using a standard and foldable container. In other words, these are the costs for which the foldable container would be competitive to the standard box. However, it is important to note that these are costs of operational processes only. It can be expected that using foldable containers leads to some additional overhead costs, that is organisational costs, but these are difficult to estimate.

From Table 5, it follows that the higher the purchase price and the higher the transport costs between depot and terminal, that is the longer the distance from terminal to depot where containers can be folded and unfolded, the smaller the financial margin for folding and unfolding, while the higher the container productivity the larger this margin. It is interesting to note that although the purchase price might be high and costly transport to a depot might be needed, high container productivity could still give the foldable container a competitive edge.

INTERESTS OF CHAIN ACTORS

To understand which parties could benefit from foldable containers and for whom foldable containers could lead to extra costs or loss of revenue, it is

helpful to take a look at the role of the parties in the chain. It is also useful to make a distinction between carrier and merchant haulage, because the interests of parties (in particular the role of the shipping companies) partly depend on the transport conditions under which the inland transport takes place. It is also important to know whose property the containers are, since this determines who bears the costs of container exploitation. Maritime containers are predominantly owned by shipping companies and container lessors, controlling, respectively, 54% and 46% of global stock. In Figure 4 the mutual relationships between the actors in the chain under carrier haulage are summarised.

Shipping companies

There are various benefits for shipping companies. In the first place, there are savings in transhipment costs if empty containers can be dealt with as a package, because this demands less handling. The storage of empty containers in a depot also provides a potential cost saving. Last but not least are the lower transport costs for repositioning over sea and/or land. However, there is a great difference between sea and land transport. Transport over sea almost always takes place under the carrier's management. To what extent transport of empty folded containers saves costs depends on market circumstances. It is true that market circumstances also play a part in land transport, but because shipping companies do not carry out this transport themselves – but buy it in – their advantage is evident. They have to buy less transport capacity, because transport of empty folded containers saves space. The costs for the shipping company consist of higher exploitation costs for containers, in case the containers are the property of the shipping company, or higher lease prices if the containers are leased from a leasing company.

Terminal operators

For terminal operators (in the seaport and the hinterland), a foldable container offers more storage capacity for empties, but this offers little commercial advantage. On the other hand, there is a loss in turnover, because if empty folded containers can be transhipped in bundles, there are fewer paid handlings.

Empty depot operators

Foldable containers also produce more storage capacity for the empty depots. Here, there is an opportunity for an increase in turnover. A disadvantage is that storage capacity is lost for the benefit of operational handlings: the process of folding and unfolding containers. Furthermore, there may be a need for special equipment to handle a bundle of empty containers.

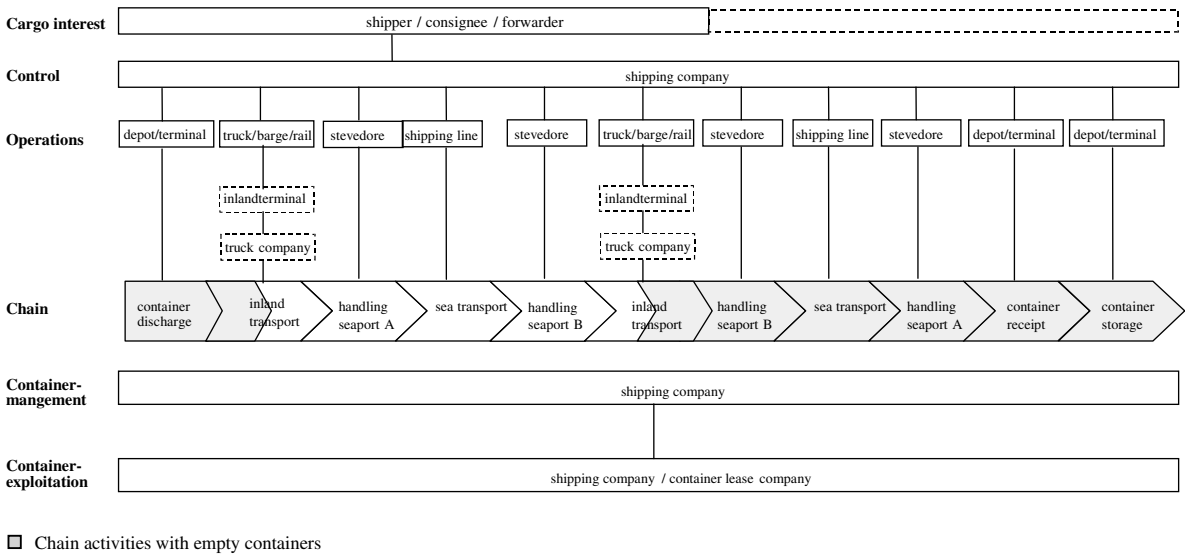

Figure 4: Positioning of the commercial interested parties in the container transport chain under carrier haulage

Inland transport operators

For the operators of inland transport – the road, barge and rail operators – the foldable container is a commercial threat. A fall in the number of paid transports of empty containers will endanger their turnover.

Shippers and consignees

Shippers and consignees have a major interest in cargo and have little or no interest in the container itself, as long as it protects well against damage of cargo. Nevertheless, they could benefit from foldable containers. Provided that carriers and transport operators pass on (part of) their cost savings to the shippers and consignees, lower transport tariffs should accrue. Whenever empty containers are folded and unfolded by the shipper/consignee (logistic concept IV), more flexibility is created in the time windows available for loading and unloading. However, space should be available for the folding, unfolding and storage of containers. In addition, the shipper/consignee must have equipment available for the handling and transport of the containers. Whenever containers can reach the shipper/consignee in an unfolded state (logistic concepts I, II and III), there is in principle no difference from the use of standard containers and as a result there are no extra costs.

Container leasing companies

Finally, the container leasing company takes up a position in the chain, different from the previous parties: the company's primary role is that of supplier of equipment. It is important for the leasing companies to provide the equipment where there is a demand for it. Attempts are made to bring this about by including clauses in lease contracts specifying the location where a container has to be returned. However, to respond effectively to demand for equipment, the leasing company has to move containers too. Therefore, the leasing companies themselves can also benefit from foldable containers: lower handling costs, lower storage costs for 'off hire' containers in the depot and lower transport costs for repositioning. The most important costs for the leasing company are higher exploitation costs.

The costs of folding and unfolding have so far been left out of the equation. Where these costs are made is clear, but who should bear them is not so obvious. Eventually, this has to be the party who enjoys the profits from foldable containers. What is clear is that the benefit accrues particularly to the actors who are responsible for container management. This will in many cases be the shipping company, but in the context of the repositioning needs of leasing companies, both parties might have a great interest. Therefore, shipping and container leasing companies should take the lead in the introduction of foldable containers.

PRACTICAL EXPERIENCES WITH FOLDABLE CONTAINERS SO FAR

If foldable containers can offer net benefits as shown, why are they then still not being used? A brief review of experiences with foldable containers might give an answer to this question.

The idea of foldable containers is not so new. In the past, many designs have been proposed. The majority of these ideas however never passed the phase of patent granting. In fact, only two designs have achieved the stage of experiments, or even a small-scale introduction in the market and these designs are at the moment still available: the Six-In-One (SIO) container and the Fallpac container (see also Konings and Thijs, 2001).

SIO container

The SIO container is a fully dismountable 20 ft dry freight box that once dismantled, can be folded, stacked six high and interlocked to the exact dimensions of a standard 20 ft × 8 ft × 8 ft 6 in container. It was launched about twenty years ago by the Swiss based SIO Container Company (SCC). A shortcoming of the first series of the SIO was its maximum gross weight of 20 tonnes (standard boxes having a gross weight of 24 tonnes). In the next generation, the carrying capacity was increased to 24 tonnes, which left only one significant difference with the standard 20 ft container: the higher tare weight of SIO (500–600 kg heavier).

The most striking characteristic of the SIO is the absence of hinges, other than the standard door hinge. The SIO incorporates seven separate elements with locking devices. Simple production and reduced manufacturing costs were important motives to choose for this construction based on dismountable parts. Avoiding the use of hinges was believed to be a key factor for success, because of well-known problems with hinges (ie corrosion, frost, bending).

In Figure 5, the main steps of the (un)folding procedure are shown. To fold a container, a three-person team with a forklift is required. SCC claims this process takes approximately 15 min. To simplify and speed up the mounting/dismounting process, an assembly jig was designed, enabling handling productivity to increase from four to six containers per hour.

Initially, SIO containers were only available for sale. In order to market the product more successfully, containers could also be leased from the early 1990s. In addition, SCC was willing to organise/operate the assembly and dismounting processes itself. In this way, containers could be delivered erected to the shipping line user, so the customer would notice almost no difference in using a standard box or SIO container.

Figure 5: The folding process of the Six-In-One container

About 2000 SIO containers have been produced – of which the actual number of units still in operation (ie being mounted and dismounted) is unknown – but this is far too small a number to speak of success.

To find the reasons for the lack of market penetration, Konings and Thijs (2001) interviewed several experts, including representatives of companies that used the SIO. Practical experiences demonstrated that particularly the costs of folding and unfolding the container formed a strong barrier. In practice folding and unfolding took far more time than claimed by the manufacturer. To insert the walls and doors is a time-consuming and difficult process, particularly when parts are slightly damaged.

Vulnerability to damage also proved a serious concern for potential users, particularly because this kind of containers is often used in areas where containers are usually less carefully handled. In addition, theft of container parts was considered as a serious problem in certain areas, that is, Third World countries. According to companies, susceptibility to damage and theft make this system vulnerable.

Furthermore, companies were of the opinion that the purchase price of the SIO is too high. Compared to the standard box prices, the SIO is about three times more expensive.

Last but not least, it was mentioned that problems may arise regarding integration of the SIO in the existing logistic chain. Most striking are the equipment problems existing container depots would have in handling a bundle of (too heavy) SIO containers, whose handling requires also additional time and space.

Fallpac container

The Fallpac is a 20 ft dry freight box which combines dismountable and collapsible features. The roof of the container is dismountable, the remaining elements are foldable. Four folded units can be stacked inside a fifth assembled unit for empty transport (see Figure 6). In this way the Fallpac container has also the same dimensions of the 20 ft standard box.

The maximum gross weight of the Fallpac container conforms to ISO standards (24 tonne), but its tare weight is approximately 4,000 kg, which is about 1,700 kg heavier than the standard 20 ft container.

To fold or unfold the container two people and a forklift are required. According to the Swedish manufacturer (Fallpac AB), the box can be folded within 10 min. Since the folding technique incorporates folding side doors, the container is suited for side loading as well as end loading. In the original design there was a problem with leakage through the side doors, but this has been solved in the more recent design.

The first Fallpac container dates from the mid-1980s. Since then some design changes have been introduced. A small test series of containers have been produced and tested with customers, including Swedish Rail. These tests took place many years ago and have not been followed up. Technical problems or serious disadvantages have not been reported, except its high tare weight. The successful flat racks might have served as a good example for the folding technique that has been chosen. Nevertheless, experiences with the Fallpac have been small-scaled.

The high tare weight might be an obstinate barrier itself, particularly when it comes to transporting and handling a bundle of empty containers. This indicates possible problems of integrating the container in existing logistic

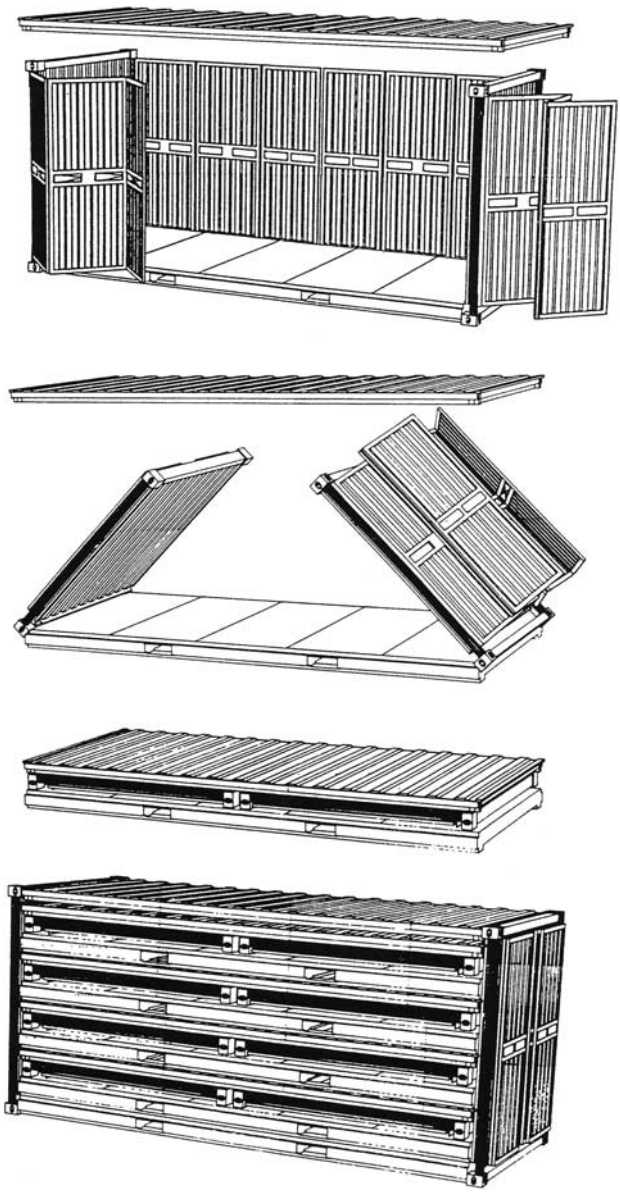

Figure 6: The folding process of the Fallpac container

processes: a problem that also affected the SIO container. Last but not least, it seems that the very limited application of the Fallpac can be attributed to little marketing and insufficient promotion of the distinct features of its design.

These experiences with the SIO- and Fallpac containers indicate that the (perceived) operational costs of foldable containers may have been prohibitive to use them. However, it is clear that other factors have played a role as well.

CONCLUSIONS

The use of foldable containers can lead to substantial net benefits in the total chain of container transport. In principle, these benefits increase as foldable containers are used on longer distances and through more links in the chain, because the costs of empty transport are reduced. The net benefits actually depend on the additional costs of foldable containers, namely:

- The costs of folding and unfolding a container (plus the associated costs of inspection and so forth);
- The additional exploitation costs of a foldable container;
- Any additional transport movements that might be needed to places where facilities for folding and unfolding are available.

The latter costs depend in part on the logistic concept that is used. Cost savings with foldable containers can be mainly achieved in transhipment and transport. Under current market circumstances the potential savings in storage costs are negligible.

An important condition to achieve cost savings is that the transport volumes of empty containers (in size and direction) are large enough to facilitate bundling. The greater the extent to which foldable containers are used into complex and fine-meshed networks, the more difficult is this to achieve. The conditions in a port-to-port concept are therefore more favourable than in a door-to-door concept.

From the perspective of individual interested parties in the chain, an important observation is that the costs and benefits of foldable containers will not automatically fall into one pair of hands, as this could lead to conflicting interests in the introduction of foldable containers. Costs for one party in the chain are often benefits for another. Whoever has an interest in foldable containers is in part dependent on the transport conditions under which the transport takes place. Decisive is who has the control and who is responsible for the physical processes.

In maritime container transport, the shipping company fulfils a central role in the logistic chain. In its capacity as director of transport and container manager, the shipping company has a substantial interest in the limitation of costs of empty transport and thus in foldable containers. This applies in particular for transport under carrier haulage. Under carrier haulage, shipping

companies also have an interest in optimisation of empty transport over land. Most likely the cost savings at the land leg of a journey are more genuine than at the sea leg.

The shipper and consignee can indirectly share in the profits from lower costs of empty transport, because shipping companies often pass the repositioning costs on to the paying cargo (imbalance surcharges, cross subsidies and so forth). The suppliers of land transport (barge and rail operators and road transport companies), however, also apply this shifting mechanism.

For those actors offering physical transport services, foldable containers constitute a threat to income. This is particularly true for terminal operators (both in the seaport and in the hinterland). The suppliers of land transport are also threatened with loss of income as a result of fewer (full paid) transport movements.

Obviously there are other – mainly logistic – conditions, such as operational flexibility and reliability, as well as technical requirements that play a part in the acceptability of foldable containers (see also Konings and Thijs, 2001). However, on the basis of the above cost–benefit calculations, a foldable container offers interesting commercial opportunities. The financial margins to compensate for the additional costs of a foldable container seem to be substantial. Here lies an important technical challenge for designers and container manufacturers to develop a foldable container, which can be operated within the financial and logistical conditions that have been outlined. Such an initiative could contribute importantly to a further optimisation of the container transport system.

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