

## **Innovations in Logistics and Barge Carrier Vessel Design for Coastal and Inland Waterway Shipping**

Jess Browning\*

### **ABSTRACT**

*The Yellow Sea region is becoming an engine of economic growth for Northeast Asia. Its growth and prosperity will depend upon how well it is able to focus on improving the efficiencies of its intermodal transportation system, infrastructure, its connection to other economies and how the system relates to logistics and supply-chain management. The region is moving towards becoming a major world economic hub and the Yellow Sea needs an innovative transportation system to be developed to support the activity that seems destined to take place. This article looks at innovative technologies that might be introduced to develop a more competitive coastal shipping system in the region. Innovations in logistics and container shipping are discussed that could greatly facilitate Incheon's situation with respect to the broader region.*

**Keywords :** *barge carrier vessel, coastal shipping, logistics, Yellow Sea*

### **I. BACKGROUND**

The Yellow Sea Region consists of the sea itself and the coastal areas bordering it, namely those of the Korean Peninsula and China. This region is becoming an engine of economic growth for Northeast Asia and its sub-regions have the potential to become a Northeast Asian economic hub. Government leaders in South Korea have developed long range plans in this regard which necessitates establishment of an efficient logistics system and includes providing more capacity to meet the demand for vessels carrying containerized cargo between Korea and other Northeast Asian destinations.

The Incheon area is a sub-region of the Yellow Sea Region that has plans to become a hub of commerce. This metropolitan city is working to develop logistics, value-added, and distribution facilities along with improved intermodal linkages to enable containerized freight to move from one mode to another seamlessly, as well as upgrading its communications and information networks. In order to help achieve these goals a regional economic development concept was developed at Inha University in Incheon

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\*Corresponding Author : Director Emeritus, Global Trade, Transportation, and Logistics Studies and Affiliate Professor, Civil & Environmental Engineering, the University of Washington, Seattle, WA 98195-3550, USA. Email:jessb@u.washington.edu.

Korea known as Pentaport. This concept brings together a cluster of various services in the context of five ports – a business port, a techno port, leisure port, airports and seaport – which is founded on the premise that a clustering and agglomeration of the right kinds of economic activity will make the whole greater than the sum of its parts.

The development of better coastal shipping, as well as inland water transport, is a critical element in application of the Pentaport model in the Incheon area with respect to marine trade and logistics services. This article looks at how trade flows might be improved by the application of innovations in logistics and container shipping. These are discussed as they might apply to coastal and inland water transport as well as shipping in the Yellow Sea Region. In applying the Pentaport model along with these innovations, Incheon's situation with regard to its location (site) being central to trade among China, Japan, North Korea, and Russia could be greatly enhanced.<sup>1</sup>

## II. MARITIME CONTAINER TRADE IN NORTHEAST ASIA

The current trend to larger ships with faster discharge rates places increased stress on land transport connections, and generates a need for faster and more efficient intermodal transfers. It also places greater demand on better marine port performance and increased investment in port facilities which has led to changes in many port's policies. As a result there is a change in port/carrier relations. Traditionally ports served mostly local trade and marine carriers came to ports to pickup the cargo. Under an emerging model, shipping lines serve regional, largely non-local trade, and feeder or intermodal service moves the cargo to the ship (UN/ESCAP, 2001). As trade increases shipping lines desire to move to economies of scale with larger ships serving fewer numbers of ports, creating load-centers or hub ports. This process puts ports and regions in competition to serve the larger vessels. Fewer ports serving these vessels places more demand on the landside transportation system to move containers to and from these load-centers. It also presents opportunities for developments in coastal and inland shipping.

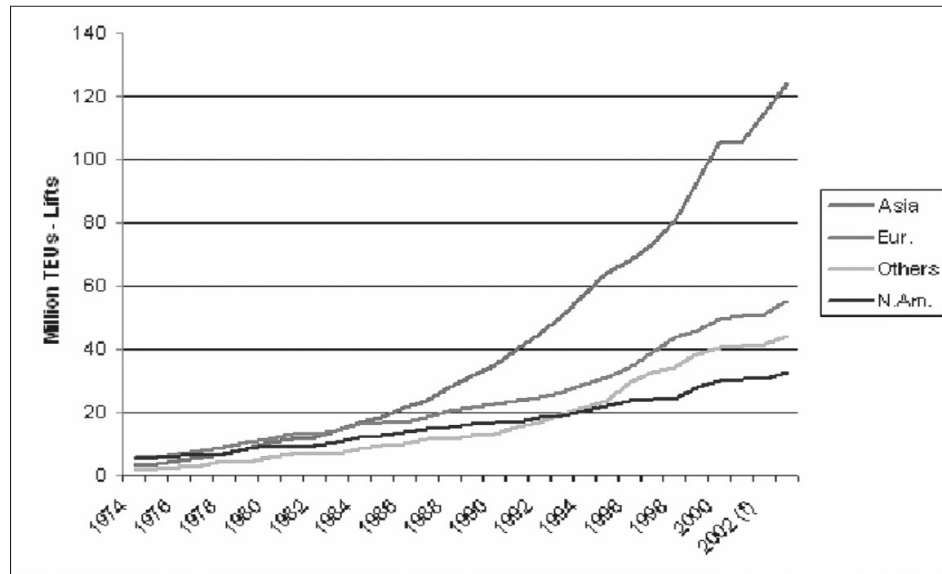
World container volumes are increasing at a very rapid pace and, as can be seen in Figure 1, Asia volumes are far ahead of others. In a recent research report it is stated that container demand forecast in Asia for 2003 was growing by 6.8 per cent and for 2004 by 7 per cent. This amounts to a total global container trade of 75 million TEUs this year and 80 million TEUs in 2004. For 2005, UBS is forecasting a 6.3 per cent growth to 86 million TEUs.<sup>2</sup> Asia has undergone tremendous structural change brought on by new markets and new technologies leading to great increases in trade as indicated in Figure 1.

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<sup>1</sup> Browning (2003) discusses Professor Fleming's geographical concepts of site and situation and describes the Pentaport model as being able to enhance the Incheon's situation with regard to trade in North East Asia.

<sup>2</sup> Donald Urquhart Shipping News, Business Times June 24, 2003.

**Figure 1: World Container Volumes**



Data Source : Clarkson Research Studies  
(CONTAINER INTELLIGENCE QUARTERLY, 4th Quarter 2002)

### III. WATER TRANSPORTATION

In most regions of the world there is heavy dependence on roads to move cargo causing congestion, pollution and other environmental problems. To resolve the problems related to dependence on roads for cargo transport, governments are seeking to increase coastal shipping's proportion of the domestic transportation of containers. There is an underutilization of coastal and inland water transport in the Yellow Sea Region (Browning and Lee 2004), which indicates a greater potential for maritime shipping within the region. Water transport by both coastal and inland waterways has tremendous potential for reducing both road and rail congestion as well as contributing to a more efficient and environmentally friendly system.

#### *Barge Network Design, Modal Shifts, and Logistics Considerations*

In Europe's inland waterways during the past decade, intermodal barge transportation has been the preferred way by logisticians to ship containers and other commodities. These developments have taken place due to the cost/time advantage over that of road transport. The cost/time advantage however has room for improvement. Network design and application can have a big impact of the cost/time equation and are significant logistics considerations. The market and other system players also impact the performance of the system. Innovations in logistics practices are needed to determine which options are best.

A general framework for barge network design described by Browning (2003) has been developed by Konings (2003). This framework describes the design variables in relation to barge transport performance variables. These are quantitative variables that can be applied to various barge networks in various types of markets such as that in the Yangtze and Yellow Sea regions. Variables include: vessel size, transport volume, cooperation for sharing, frequency of service, and circulation times. Another cost model described by Browning (2003) includes various modes (road, rail, inland waterway, sea) and intermodal transfer (marine terminals, rail terminals, and inland terminals) as cost components. The model consists of four progressive stages and the author states that:

It is based on the premise that unit costs of transport vary between modes, with the steepness of the cost curves reflecting the fact that, for volume movements, sea transport should be the cheapest per ton-km, road transport should normally be the most expensive (at least over a certain distance), and waterway and rail costs should be intermediate (Banomyong and Beresford, 2000).

At ports and inland terminals, a freight handling charge is levied without any material progress being made along the supply chain; the cost incurred here are therefore represented by a vertical “step” in the cost curve. The height of the step is proportionate to the level of the charge. Depending on the route chosen, the combination of modes and cost will be different. The purpose is to find the most competitive route cost wise. The model may also be used as a contributory tool in the debate over the value of time in freight transport operations.

Both of the above models provide innovations in logistics practices that should be of great help to logisticians and others in determining the costs in shipping containers from point of origin to destination by different modes and various routes when inland and coastal water transport as well as short sea shipping is used. The barge network design framework should be of specific interest in evaluating the conditions (transport markets and waterway infrastructure) that need to be considered in optimizing the best performance for barge operations given vessel size and frequency of service for the distance to be traveled (Browning, 2003). This is referenced in an example given later in this article.

### ***Logistics and Shipping***

Logistic is changing rapidly as a result of globalization and as the process unfolds, the trend is that only a fewer but larger seaports will serve as a hub for economic regions with inter-modal transportation networks linking local ports and neighboring hinterlands. Containerization of marine cargo along with new technologies has enabled global trade to expand at extremely rapid rates over the past four decades. There is growing concern however, that the shipping industry’s method for coping with the growth of container traffic by building bigger ships to achieve greater economies of scale may be reaching its limits. Between 1965 and 2000, the shipping industry went from zero to 226 million TEUs containers. The growth of worldwide container projections indicates a worldwide

TEU level of 550 million by 2025.

The traditional response for industry to container trade growth to commission larger containerships of 6,000 and 8,000 TEU is forcing port communities to deepen channels, devote more land to container operations, build on-dock rail connections and make other investments to remain competitive, especially if they want to become a hub port. The costs are staggering; environmental and land use constraints are impinging on the ability of ports to make capital investments; and the peak volumes of containers projected to move through ports on and off these mega containerships threaten to increase congestion, and even nullify the efficiencies that the shipping lines are attempting to achieve through these large capacity vessels (Browning, 2003)<sup>3</sup>. It is predictable therefore, that the number of post-Panamax vessels (too large to pass the Panama Canal) calling at hub ports will increase but also smaller vessels needed for feeder services among small ports and serving hub ports will also increase.

#### IV. BARGING CONTAINERS ON COASTAL AND INLAND WATERWAYS

With the emergence of “hub ports” in ocean transportation, there is a growing interest in short sea shipping to move containers between ports both in coastal trade for a given economy and between economies. Water transport to complement land transport is becoming important in many regions to relieve road and rail congestion as well as reduce environmental impacts. Concurrent with this development is interest in improving the efficiency of moving containers from inland ports to the ocean ports and hub ports via short sea shipping. This has led to renewed interest in the role of barge transportation for container movements in inland water transport and short sea shipping which may possibly lead to a decentralization of hub port activity in the future. A study by the World Bank indicates that major seaports view, inland container terminals as competition. Smaller ports may profit by competing to be the point of entry and exit for the inland container terminals (ICT), which may lead to a certain degree of de-concentration (World Bank, n.d.).

Water transport has many distinct advantages over the other modes. Pinto (2001) notes that as routes are developed along existing rivers, canals and waterways, they do not have the problems associated with acquisition of “right-of-way” as in the case of road and rail. He states that the cost per kilometer of waterway development is normally much less compared to that of an equivalent length (or capacity) of rail or highway and that the cost of maintenance for a waterway is also usually less than that of rail or road.

A vessel earns income by moving goods from one location to another. Time in port is costly so larger vessels need to unload their larger loads at fewer ports (i.e., hub ports).

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<sup>3</sup> Browning (2003) was compiled in part from discussions with Tornqvist who patented the system in March 1998.

From these hub ports, containers are carried to their final destination on various modes of transportation that may include rail (sometimes with containers double-stacked), trucks, and container barges (Browning and Lee, 2004).

### *Alternatives to Traditional Container Barge Operation*

The traditional means of barge movement has been by being towed or pushed between ports. Alternative ways of moving barges is now being explored. This has been to reconsider the LASH (lighter aboard ship) and “float/on float/off” (FLO/FLO) technologies for carrying barges. LASH is also termed “lift/on lift/off” (LO/LO), and the rationale for the lash or LO/LO applies to the FLO/FLO methods of transport for barges and other equipment. The hulls of all the FLO/FLO vessels are semi-submersible (like a floating dry dock) and are capable of accommodating the cargo in multiple separate float-on / float-off barges or watertight containers. The FLO/FLO technology is being looked at as a more efficient system than the LASH or LO/LO technologies. It offers a unique solution to increasing volumes of marine cargo without the concern of deepwater channels, ports, and larger terminals that are needed to handle mega ships.

**Figure 2.** The FLO/FLO Type Barge Carriers



*Source : Dockwise (2003)*

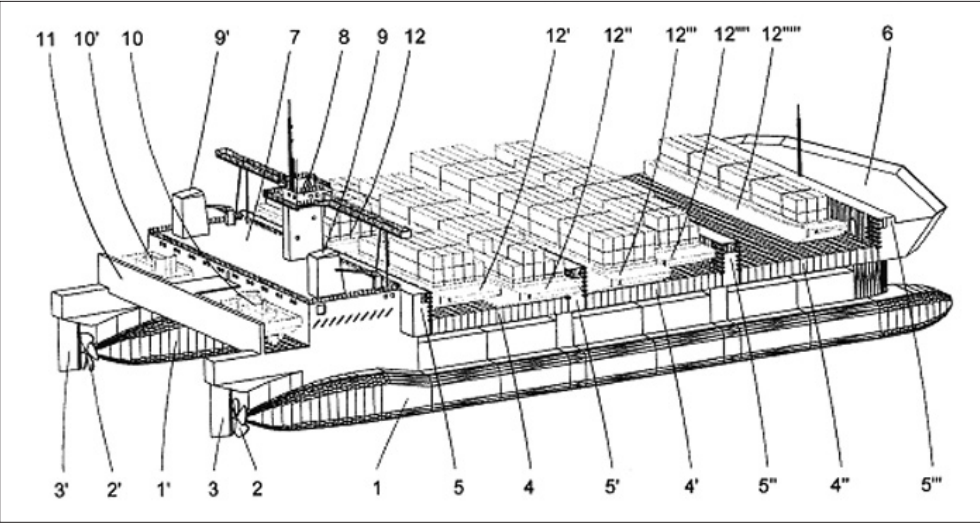
FLO/FLO is now being used by the military and the shipping industry for loading and moving barges and other equipment. One example of the FLO/FLO design is shown in Figure 2. It is a semi-submerged vessel that can submerge its loading deck to sufficient depth for loading barges and other equipment.

In Europe, a FLO/FLO concept called the Combined Traffic Carrier Ship/Barge (CTCB) is being developed and is based on what they term the Trans Sea Lifter (TSL) that is shown in Figure 3 (Peterilini, 2001). This is a catamaran type vessel that is designed to carry barges used in inland water navigation. The vessel is designed to partially submerge and loads/unload barges (item 12 in Figure 3) in a similar fashion to those vessels as shown above. The TSL is intended to make regularly scheduled stops at the entrance to inland waterways to pickup and drop off barges in a staging area. The barges would be moved to and from inland ports by tugboats while the TSL moves on to



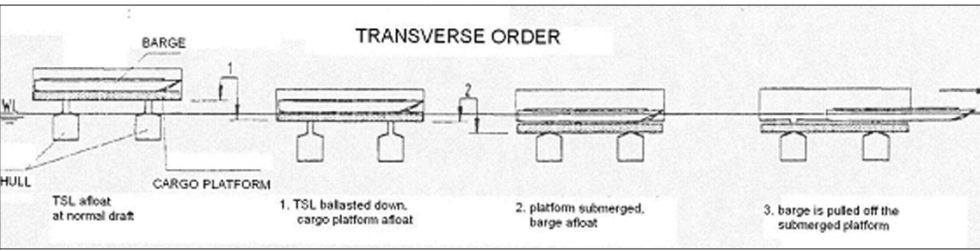
its next stop on its round trip voyage. The proposed vessel's dimensions are length 182.3 m; draft 10 m, and width 76.5 m. — the length of the Europe Ila standard sized barge. This vessel would be able to carry six of the Europe Ila barges with 102 TEUs each for a total capacity of 621 TEUs. The estimated cycle time for submerging floating off & on all barges, and re-floating is 90 minutes (Peterlini, 2001).

Figure 3. Side-loading Trans Sea Lifter (TSL)



U.S. Patent Number 6,550,408 April 22, 2003

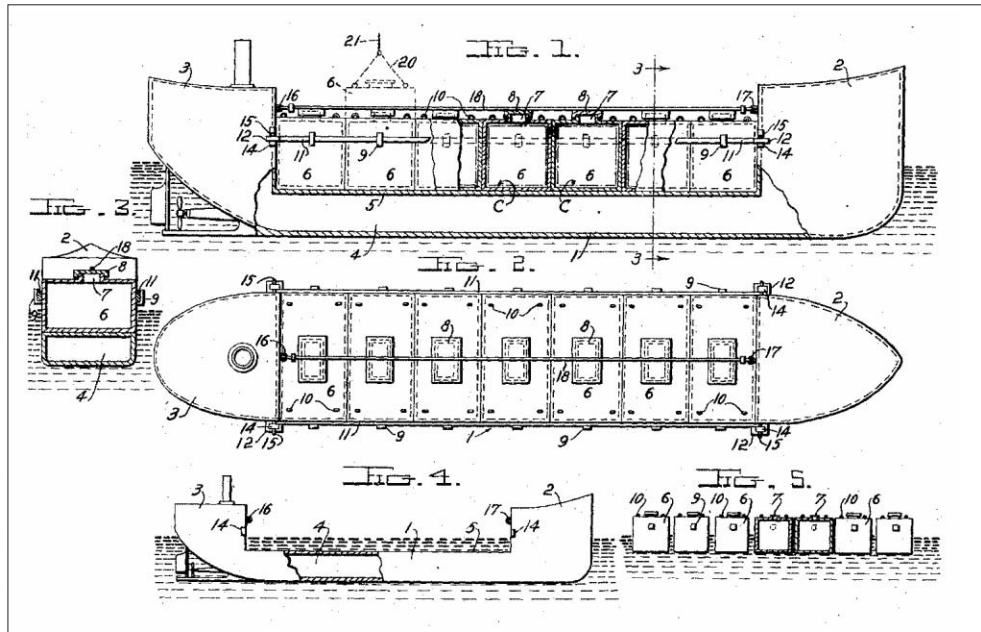
Figure 4. Side-loading Trans Sea Lifter (TSL)



U.S. Patent Number 6,550,408 April 22, 2003

In looking for innovations in this type of technology, a search of the U.S. Patent office files shows that there are three patents for FLO/FLO type technology that loads from the side in addition to the Dockwise vessels and the TSL noted above. These are shown in Figures 4-7. Figure 4 is an end view of Figure 3 showing the transverse order of semi-submerging and unloading a barge. Since the vessel is a catamaran type and stands higher in the water to reduce water drag, the vessel has an additional submergible platform (4) shown in Figure 3 (step 2 in Figure 4) that also has to be lowered to enable the barges to float free.

**Figure 5.** Semi-Submerged Side-loading Floating Container Vessel

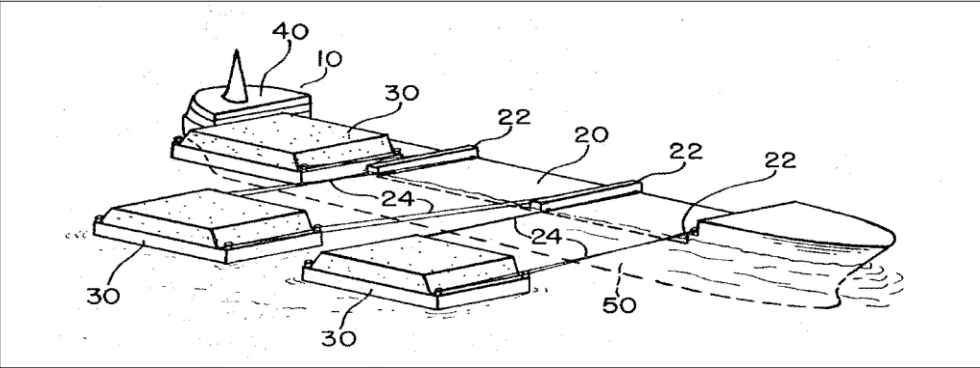


U.S. Patent No. 2,406,084 August 20, 1946

Figure 5 shows a semi-submerged vessel that is ballasted to stay at the same depth and the containers remain floating during the voyage. The vessels in shown Figures 6 and 7 simply ballast down and the various cargo containers are free to float away from the vessel.

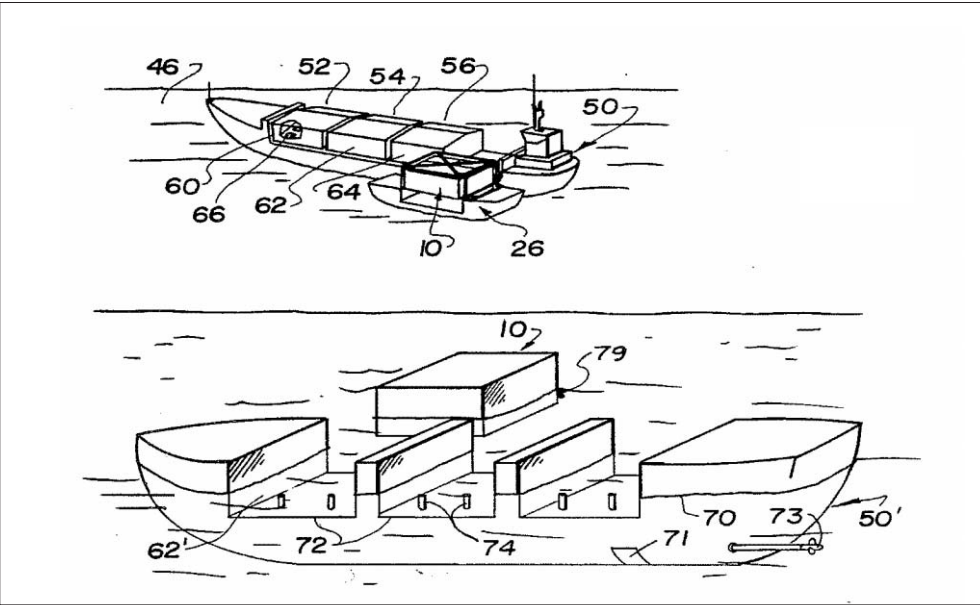


**Figure 6.** Semi Submersible Side-loading Barge Carrier



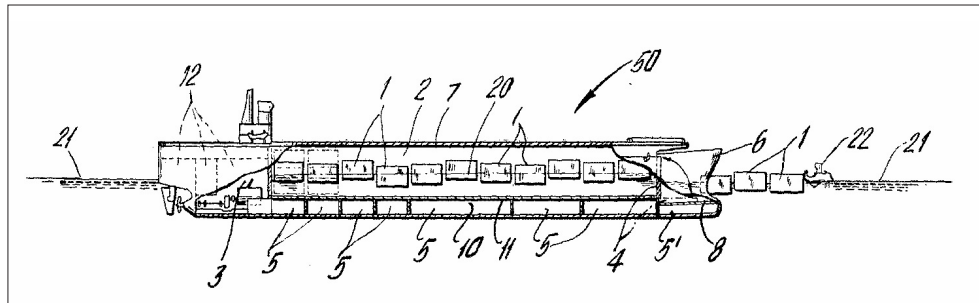
*U.S. Patent No. 3,550,036 January 19, 1971*

**Figure 7.** Semi-Submersible Side-loading Floating Container Vessel



*U.S. Patent No. 4,898,112 February 6, 1990*

One of the patents for semi-submersibles is a front-loading vessel shown in Figure 8 that can load containers floating at various heights through a sea-door in the bow. It is shown partially submerged with a tug (22) moving the containers into position.

**Figure 8. Semi-Submersible Front Loading Vessel**

*U.S. Patent No. 3,939,790 February 24, 1976*

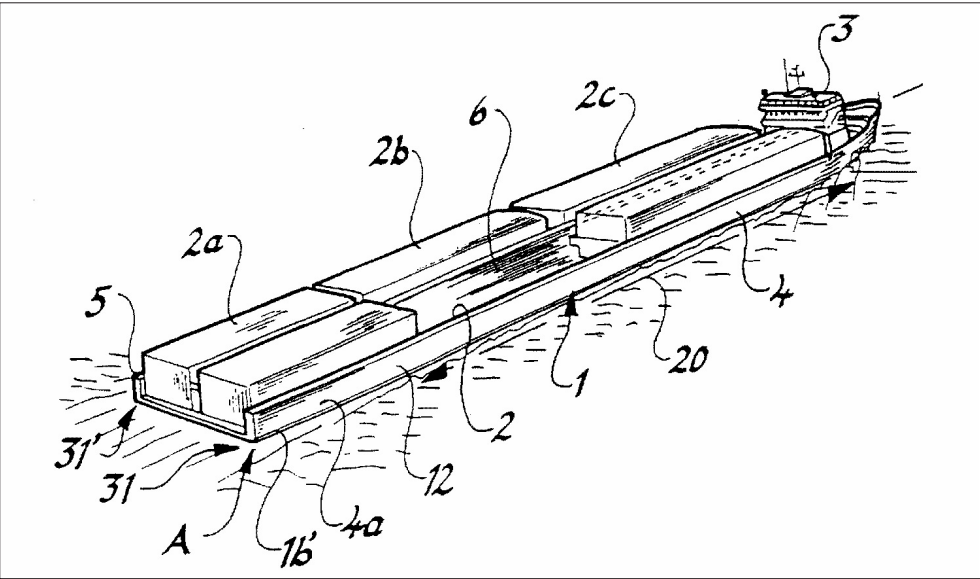
Figure 9 is a stern-loading vessel with a deck space of 32 x 140 m that could hold three container barges stacked 15 wide by 23 long by 3 high or approximately 1000 TEUs.

In addition to the vessels illustrated, a further search of the U.S. Patent office files reveals that there are 5 patents and one application for FLO/FLO type technology for vessels that load from the stern as opposed to the side and front-loading vessels noted above. One of these is a barge carrier that has a “trapezoidal” hull design (see Figures 10 and 11) (Browning, 2003).

**Figure 9. A FLO/FLO Type Yacht Carrier**

*Source : Dockwise (2003)*

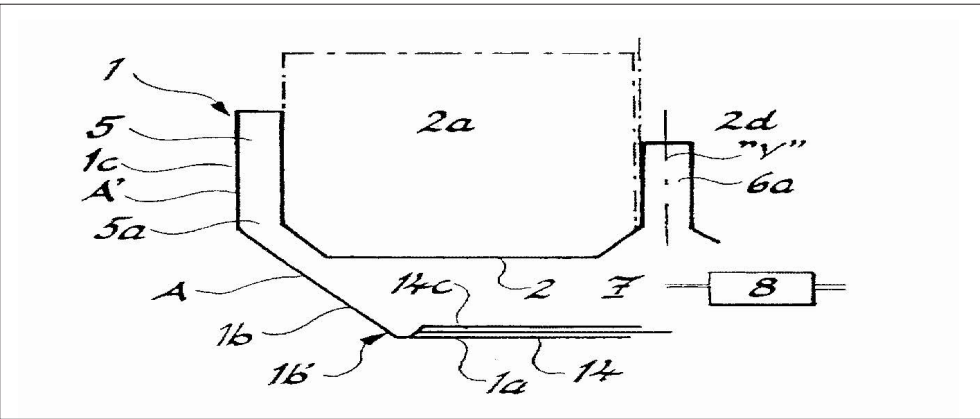
Figure 10. Stern-loading Jumbo Barge Carrier



U.S. Patent No. 5,722,341 March 3, 1998

The trapezoidal hull shown in Figure 11 increases the stability of a vessel designed for barge carrying. Tests run on the innovative trapezoidal hull have shown it to reduce propulsive resistance, increase stability and deck space and cubic capacity of the cargo compared to a conventional ship with the same displacement. A U.S. Department of Energy study stated that the “unique trapezoidal.... suggest some advantages over the traditional ship designs in propulsive efficiency and sea keeping ability” (US Department of Energy, 1990).

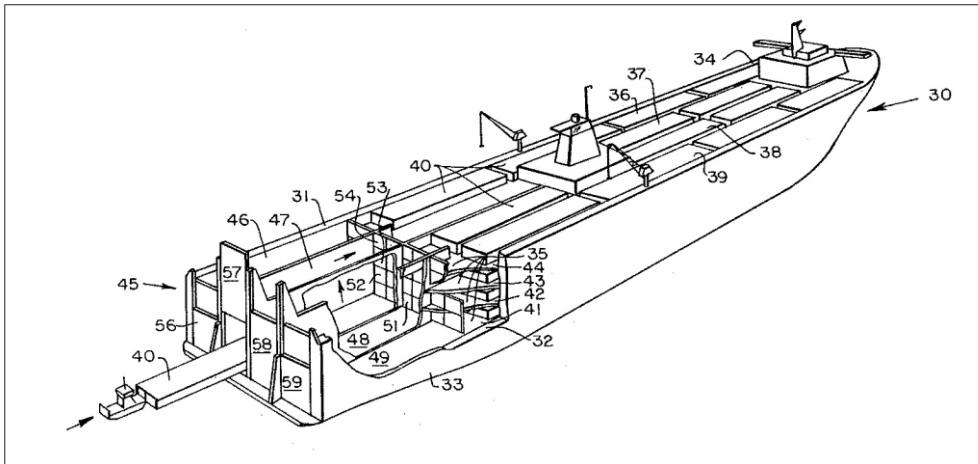
Figure 11. Trapezoidal Hull



U.S. Patent No. 5,722,341 March 3, 1998

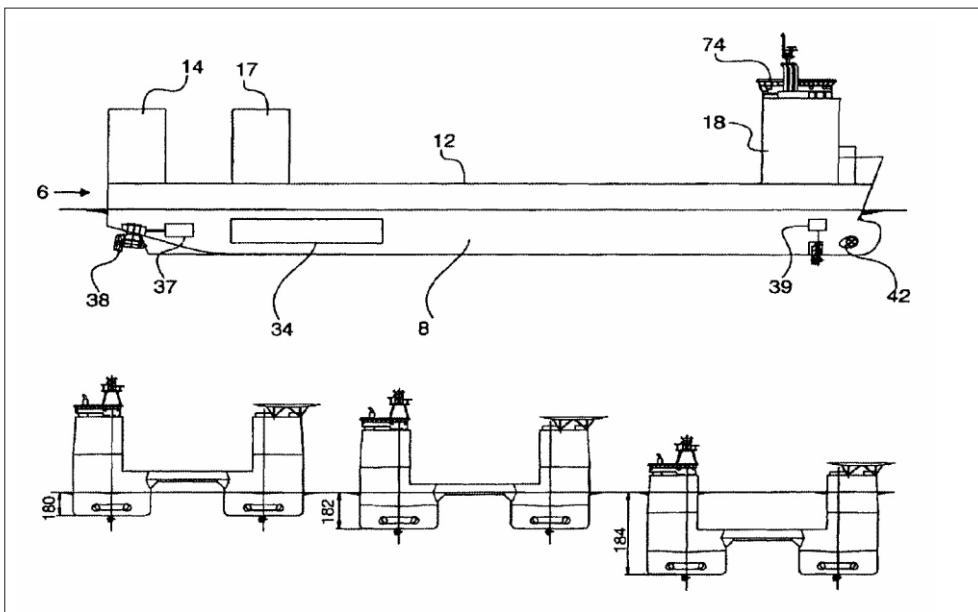


**Figure 14.** Semi-Submersible Stern-loading Barge Carrier Vessel



*U.S. Patent No. 4,147,123 April 3, 1979*

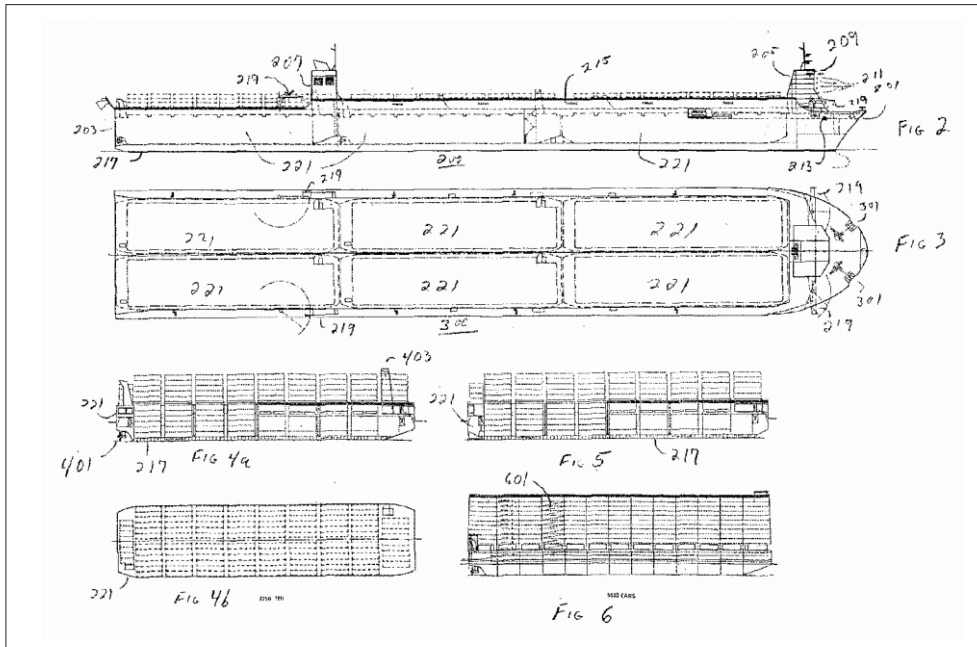
**Figure 15. Semi-Submersible Stern-loading Vessel**



U.S. Patent No. 6,688,248 February 10, 2004

The stern-loading barge carrying vessel shown in Figure 16 is a patent application that appears to emulate the patented Jumbo Barge Carrier shown in Figure 10.

**Figure 16.** Semi-Submersible Stern-loading Barge Carrier Vessel



U.S. Patent Application No. 2002078873 June 27, 2002

The six Figures 2 to 7 (inclusive) show technologies that have been developed for side-loading FLO/FLO vessels and Figure 8 shows a front-loading vessel while figures 9-16 show technologies that have been developed for stern-loading FLO/FLO vessels. These illustrations demonstrate the perception of many vessel designers that FLO/FLO technology is a viable way to improve efficiencies in various methods of water transport where a semi-submersible or semi-submerged vessel is employed. In either case, a FLO/FLO mother ship makes it possible for a port to handle increased capacity without investing in deep channels. The barge carrier can discharge and reload its barges in deep water outside the main port area. Essentially, the mother ship arrives in a sheltered area of a load center port and ballasts down allowing the barges to discharge and/or load by floating on and off the vessel. Tugs tow the barges to marine terminals in the hub port or to ports on inland waterways and are then stevedored as conventionally.

The larger barges require only 6 to 9 meters of water, well within the capabilities of most of today's container ports and many inland waterways. The smaller barges can be built with a draft depth to operate in the waterways they are designed to serve. It is important to note that the barges can be dispersed among several terminal facilities to make better use of the port facilities and/or underutilized ports while avoiding road congestion as well as rail congestion. Unloading and loading of the barges can take place at a more leisure pace during regular working hours, thus avoiding overtime expense.

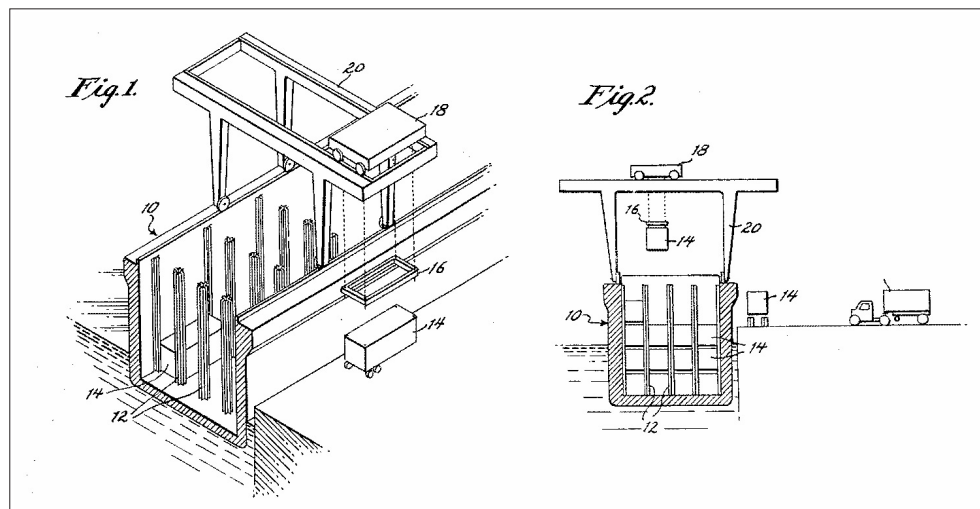


Improved efficiencies can also be demonstrated where the cost of modal shift (or transfer) from sea to inland water transport as describe by Browning (2003) can be reduced as well as the vessel charges (the slope of the line for sea transport) and terminal handling costs (the vertical line between modes).

### *The FLO/FLO Vessel as a Floating Transshipment Terminal*

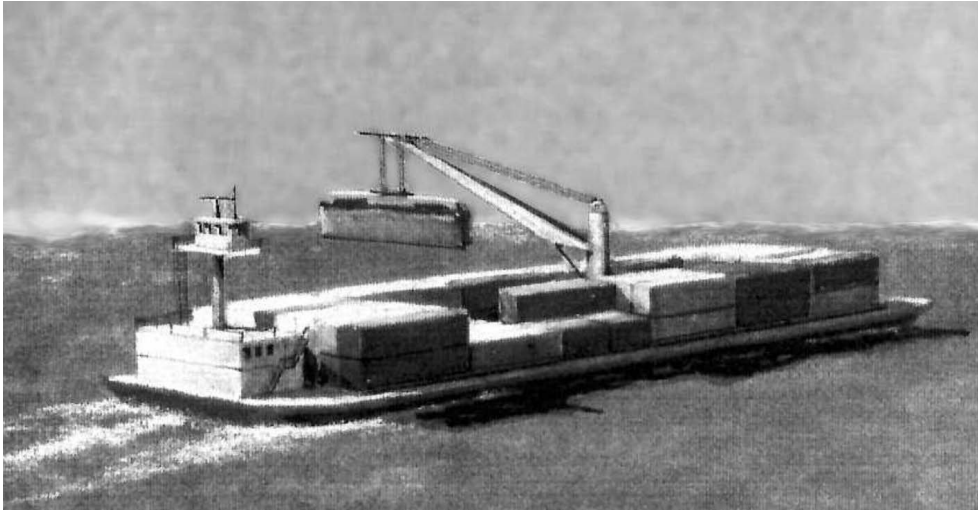
In the case of short sea shipping either for direct shipment or transshipment to out ports 645 to 1610 kilometers from coastal and inland waterway staging areas, a smaller mother ship would be used to carry multiples of smaller barges. In the case of ocean service vessels, a larger mother ship would be used to take advantage of economies of scale. Both types of vessels, large and small can be designed with an on board crane mounted on side rails to shift containers from one barge to another while underway maximizing loading efficiencies. Figure 17 shows a patent assigned to a division of Fruehauf Trailer Company from the 1960s that describes the design of a container vessel with an onboard crane.

**Figure 17. On Board Container Crane**



*U.S. Patent No. 2,963,310 December 6, 1960*

A Floating Container Terminal (FCT) that is shown in Figure 18 has been designed to reduce barges' and feeders' calling -time in the port area and to provide an alternative for internal road transport in the Rotterdam Port area. Instead of making several calls at ports barges and feeders make one call at the FCT which has its own board crane. Containers are directly transhipped from the barge or feeder to the FCT and vice versa. The FCT makes a 24-hour round trip at a fixed sailing schedule along the terminals, focusing on Rotterdam Port terminals, namely Eem-/Waalhaven, Maashaven and Merwehaven. The cycle time of barges in the Port of Rotterdam is reduced by 4.5 to 7 hours – a reduction by 14 per cent to 22 per cent of the average cycle time.

**Figure 18.** Floating Container Terminal (FTC)

*Source : Peterlini (2001)*

According to Peterlini (2001), the FCT is 94 meters long and 22.8 meters wide with one onboard crane and a maximum capacity of 350 TEU. The FCT crane can move 15 and 20 containers per hour, which amounts to about 250 TEU (170 containers) maximum per day. He states that congestion in the Port of Rotterdam area will only increase and that new concepts should be introduced such as the FCT to reduce the cycle time of barges in the Port of Rotterdam. His opinion is that when barge operators become accustomed to this new type of technology, they will be able to improve fleet efficiency while reducing their costs.

The loaded barges can be built with cells similar to that shown in Figure 17 to prevent side-to-side movement of containers. They can be un-stacked from one barge and restacked on another for discharge at the next port of call. This would simplify the logistics of loading containers at an inland port on a barge that would be making several stops in direct trade or feeder trade. The mother ship in essence would become a floating terminal similar to that reported in the study on Maritime Technologies for Marine Transport (Peterlini, 2001).

A FLO/FLO designed vessel with an onboard crane would be able to perform a transshipment function while underway in calm seas or in a sheltered area arriving at a river mouth, a coastal port, or a hub port with the right combination of containers on a barge that would be floated off and replaced with another in a matter of minutes or, at most, a few hours which would greatly reduce cycle time and costs at ports for the vessel. The barges can be dispersed among several terminals to make better use of the port facilities and avoid road congestion as well as rail congestion. It can help smaller under utilized ports at coastal and inland water hinterlands normally served by road or rail transport. This would help the larger ports in reducing container dwell time and expensive

real estate needed for container storage. A recent *Journal of Commerce* article (Mongelluzzo, 2004) on the LASH barge carrier describes this need not only for reduced cost of transit but also for the ability to serve shallow draft ports and congested ports without delaying the mother vessel.

V. COMBINING LOGISTICS AND TECHNOLOGY

Figure 19 illustrates a typical short sea shipping system in the absence of cabotage laws where multiple container laden vessels are able to engage in trade between Coastal Marine Terminals B, C, E, and F and the Inland Water Terminal D as well as the Hub Marine Terminal A. In this scenario, there is an advantage in time and simplicity because each vessel is able to move from point to point as needed to meet delivery requirements. The disadvantages are that more vessels are in the system than is necessary causing congestion in the terminal areas and confusion in the supply chain. There is redundancy not only in vessels and capital equipment but also in personnel needed to operate the equipment in this transportation system resulting in higher than needed costs.

Figure 19. A Typical Short Sea Shipping System

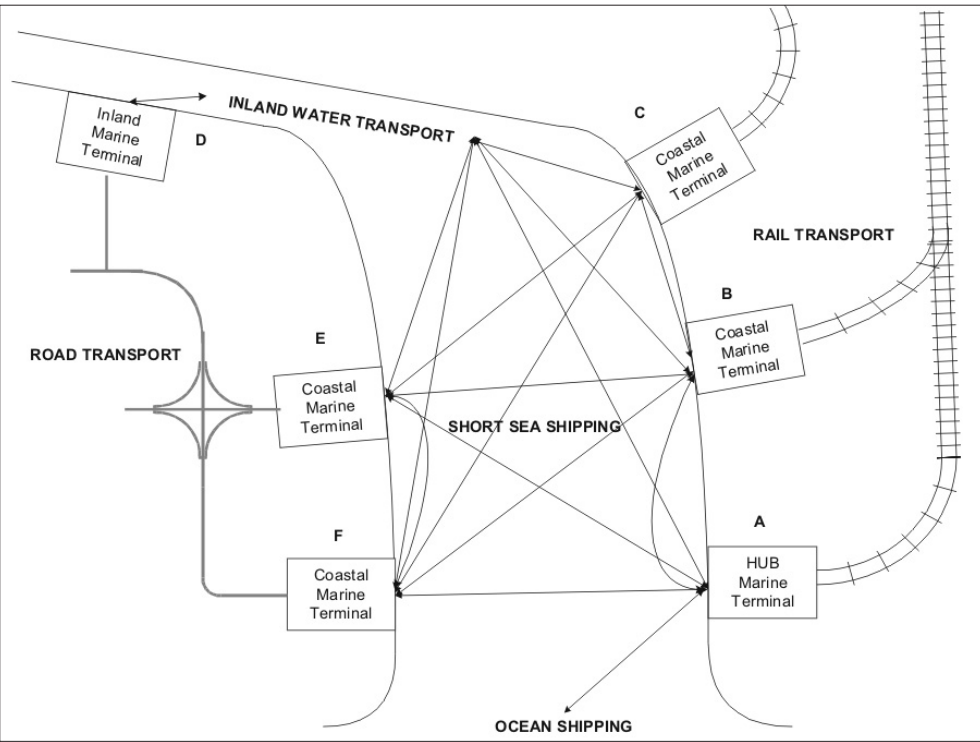
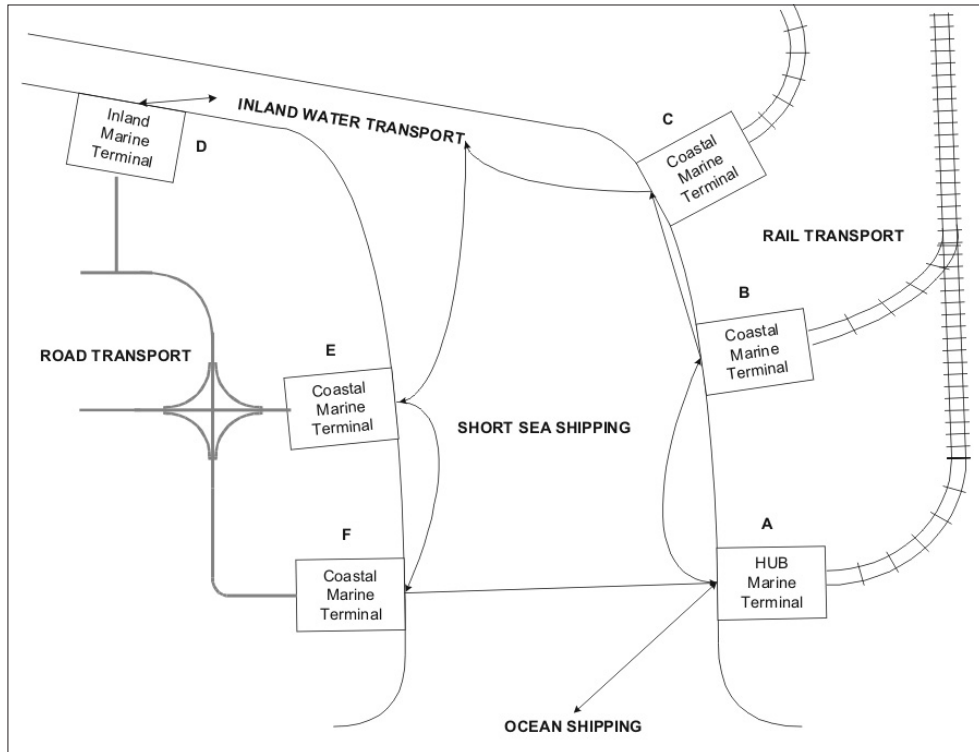


Figure 20 illustrates a hypothetical short sea shipping system (also in the absence of cabotage laws) that is based on advanced logistics practices and innovative container barge carrier technologies as described and illustrated earlier.

**Figure 20.** SSS System with Advanced Logistics and Innovative Barge Carrier



In this scenario, one FLO/FLO container barge carrier using floating container terminal technology is able to travel a circuit between all the terminals in sequence. The vessel does not call at the terminals but anchors a short distance away, where it drops off (floats-off) a barge containing the containers destined for that terminal. Each barge that is picked up (floats-on) has been loaded so that containers are grouped for each subsequent terminal in the circuit. While underway as described earlier, the vessel's onboard crane performs as a floating terminal distributing the containers onboard between barges so that when the vessel makes the next call the off-loaded barge will contain the proper containers. The circulation or cycle time for each complete circuit in the system would depend upon on the size of the vessel and barges and on those factors listed in Koning's Framework as noted earlier: The distance; sailing speed; quality of waterways; number of calls; waiting time; transport volumes; and waterway dimensions. Surface transportation congestion (road and rail) or lack thereof would also be a factor. The time-sensitive nature of the shipments would also be a factor. If a cycle time of 24 hours is needed and volumes merit it, the system could be designed accordingly.

Advantages of this type of system are in the savings in capital equipment, labor, and vessel waiting time. It makes it possible to spread the concentration of containers over a larger area and take advantage of under utilized ports. It can reduce congestion around container terminals, reduce peak demand and dwell time in the terminal, and enable the terminal to load and unload containers on the barge at a more uniform pace. Disadvantages of the system are upfront capital cost for a more expensive vessel that requires more technological knowledge for construction and operation. Time sensitive containers that are loaded at the most distant terminal from the hub port in rotation for ocean shipment may find the delay unacceptable, however the design of the circuit as noted above should take this into consideration. Koning's model for barge network design described earlier should be helpful in this regard.

## VI. SUMMARY AND CONCLUSIONS

This article describes innovative technologies for FLO/FLO vessels that could be introduced to improve shipping efficiencies and reduce costs in the region. The maritime industry is facing a crisis – the shipping container has enabled the world to trade commodities on a scale that was unimaginable just a few decades ago. As noted earlier in this article, increases in trade motivates marine carriers to move to larger ships serving fewer numbers of large hub ports or load centers. Fewer ports serving these vessels places more demand on the landside transportation system to move containers to and from these load-centers. In order to accommodate the increase in container volumes moving in and out of marine ports without creating larger vessels and ports The FLO/FLO container barge carrier may be a good alternative to existing methods.

Innovative logistics methods such as the models for barge framework design and modal transport planning need to be used in a systems type approach to solving container transport problems. A hypothetical short sea shipping system using barge carrier and floating marine terminal technology was presented and discussed to show the feasibility of this innovative technology. This FLO/FLO barge carrier system along with onboard crane technology should be considered for coastal and inland water transport as well as short sea shipping in the Yellow Sea Region. It also has application in a broader context for ocean shipping to and from regions beyond the Yellow Sea.

Serious consideration should be given to government-sponsored research leading to the development and application of FLO/FLO type vessels (including the floating terminal type) for carrying container barges. In the context of the Pentaport model, this effort could ultimately improve transport efficiencies and improve the environment while reducing costs and congestion in road and rail transport. In doing so it would greatly facilitate Incheon's situation with respect to the broader region.

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