Innovative Waterborne Logistics for Container Ports

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A new developed and internationally patented type of harbour vessel, named ***Port Feeder Barge****, can considerably improve the internal container logistics in many major container ports. The double ended and self propelled pontoon type vessel which has a loading capacity of 168 TEU is equipped with its own full scale container crane. The new type of vessel can shuttle containers within ports and can also handle containers from inland barges independently from quayside equipment and carry them to/from deep sea terminals where no berths are blocked any more by numerous inland barges and no huge gantry crane has to inefficiently serve the small vessels.*

Keywords: container transhipment, floating terminal, intermodal connectivity, intermodal harbour vessel, intra-port haulage.

1 Task

The efficiency of container transhipment procedures within the port is essential for the competitiveness of major container hubs. Containers have to be transferred between seagoing (deep sea and feeder vessels) or between seagoing vessels and inland barges. As the vessels which have to be connected are not always berthing at the same facility a lot of intra-port container shiftings are resulting out of the transhipment procedures. Beside that it is unavoidable that there are a lot of movements of boxes (either full or empty) between the various sites of a port anyhow. Even if there is only one major terminal in the port some boxes have to be carried to other places within the port for stuffing/stripping, M+R, fumigation or long term storage.

Intra port container logistics can be separated into following fields:

- Intra-port haulage
- Feeder operation
- Inland barge operation

1.1 Intra-port haulage

Statistics on port's internal box movements are in principle difficult to generate because the deep sea terminals mostly do not know about the final destination of a container when it is leaving the terminal for further on-carriage. It is the same when a container is being delivered to the terminal. The point of origin is not always known to the terminal, especially if it is delivered by truck.

The intra-port volume is predominately carried on the road. E.g. it is estimated that within the port of Hamburg approx. 250,000 containers have been carried by truck in 2009 (which is corresponding to approx. 375,000 TEU).[1, 2] From Fig. 1 it could be derived that intra-port container haulage – even if it can not be exactly determined – is not a negligible fraction of the total road haulage within the modal split of the port's hinterland volume.

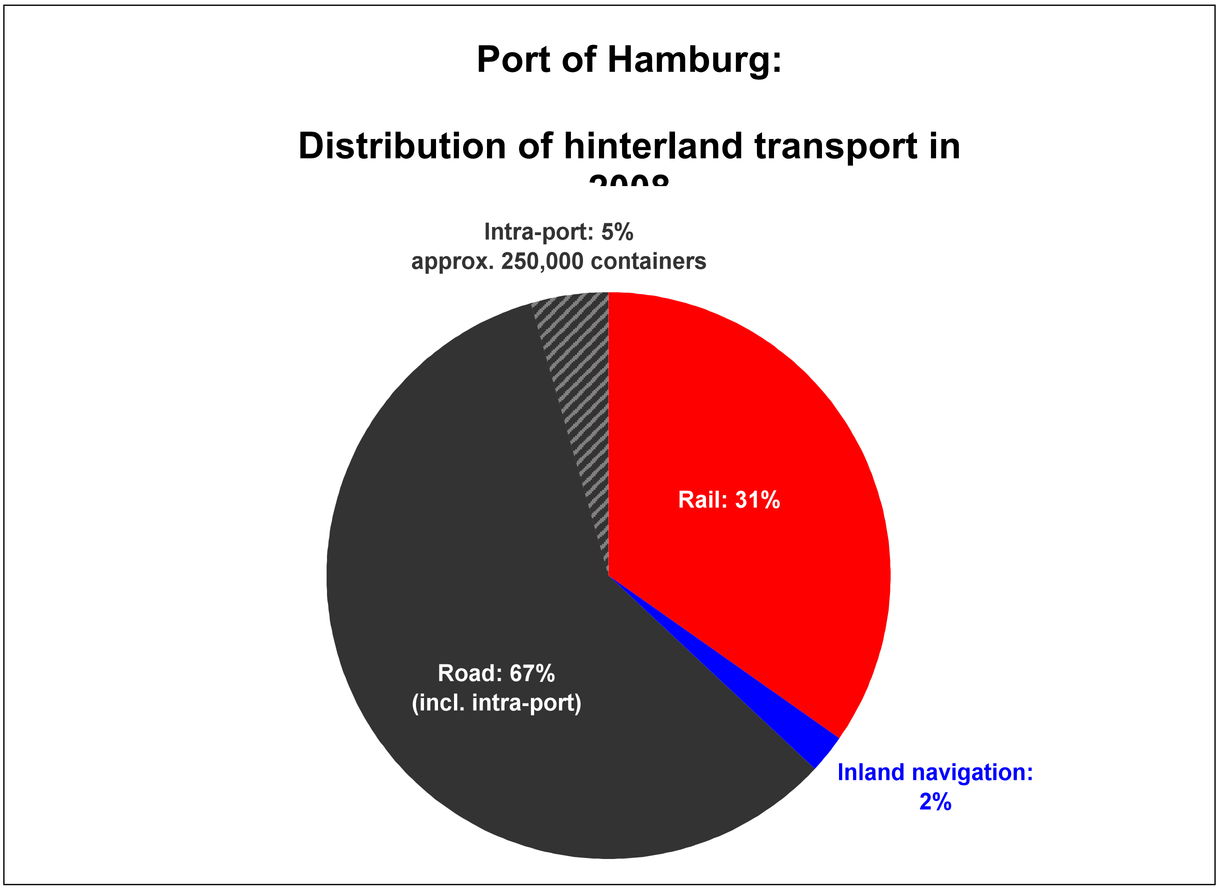

Fig. 1 (source: HHM e.V.)

CTD, the biggest container trucking company in Hamburg (subsidiary of HHLA) with an estimated market share of slightly less than 50%, realised that ⅓ of its intra-port volume is terminal-to-terminal.[2] More than half of its volume is between a terminal and off dock facilities whereas the remaining is between two off dock facilities. Due to its dominant position it is anticipated that CTD's figures are representative for the entire intra-port trucking volume (see Fig. 2).

[1] In Hamburg the average TEU ratio is approx. 1.5 TEU/box
[2] Information by Marcus Bönning, Managing Director, CTD GmbH, November 2009

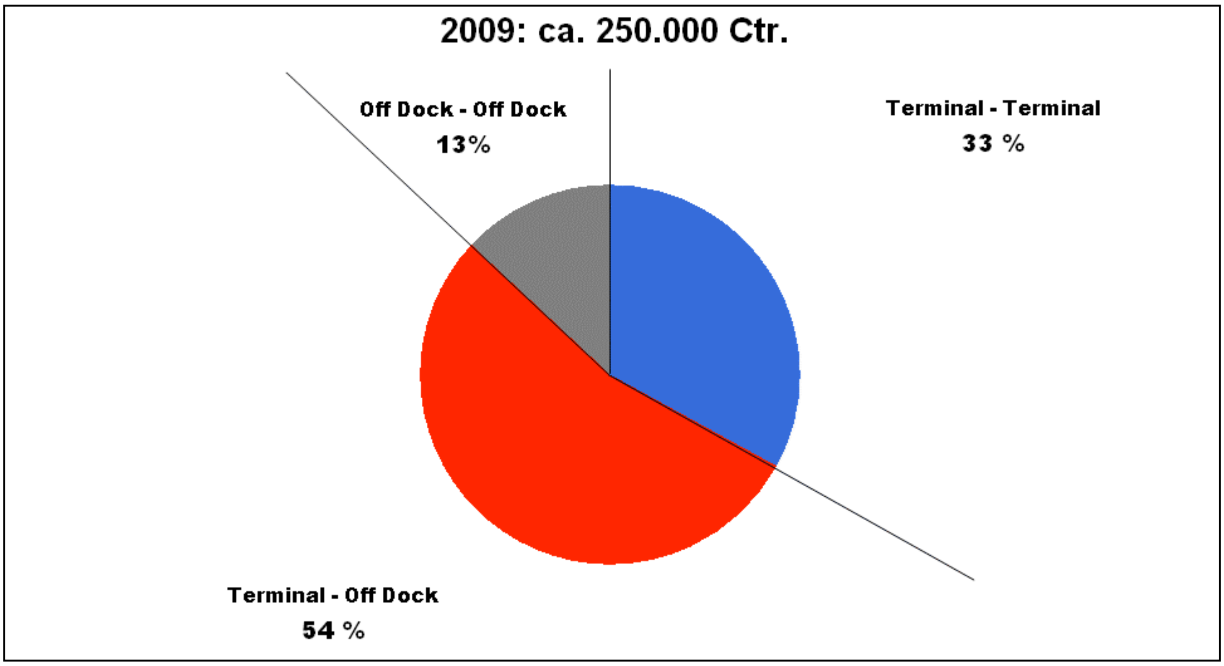

Fig. 2: Split of intra- port container transport in Hamburg

In Hamburg no regular shiftings of containers between the various facilities within the port are executed by train. This is simply due to the fact that railway carriage of containers requires either a minimum number of containers (to fill a block train) or a lot of time consuming shunting is involved. In both cases booking of such shiftings is not possible on short notice as the railway system in general is not flexible enough to quickly respond to such a demand.

Instead of shunting even train operators themselves are subcontracting road hauliers for the last mile within the port if the final destination of a container is not the arrival terminal of the train. This is the case not only with the numerous small private newcomers which have entered the market and are operating from only one terminal but also accepting boxes from other terminals. Even state owned giant Deutsche Bahn and its subsidiary Transfracht are subcontracting road hauliers within the port.

The total intra-port container volume in 2009 by road and waterway is estimated to approx. 290,000 containers respectively 435,000 TEU [1] while the total throughput was 7.0 Mill TEU.[3] As a result only less than 15% of the entire intra port volume is carried on the water.

The reason is very simple: Inland barges or pontoons employed in intra-port container transportation are dependent from the quayside gantry cranes for loading/discharging. However one move per gantry is already exceeding the costs of the entire trucking. Naturally two moves are needed and the barge has to be paid as well. Hence in most cases intra-port barging of containers is not competitive unless the liftings by the quayside gantries are subsidised by the terminals.

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[3] Information by Hafen Hamburg Marketing e.V. (HHM), 2010

Fig. 3: Typical view on Hamburg's Köhlbrand Bridge during the peak times of 2007/2008 (photo: dpa)

1.2 Feeder operation

In multi terminal ports common feeder services have to accept and deliver containers from/to all facilities where deep sea vessels are berthing. For this reason the feeder vessels have to call at all terminals within the port – sometimes even if only a few boxes have to be handled. As a consequence each feeder vessels which called Hamburg in 2007 had to berth in average at 3.8 different facilities (incl. waiting berths) [2] [3]. That is why the feeder lines are already a major customer of the trucking companies. Otherwise the number of calls within the port would have been much higher.

In Hamburg smooth feeder operation is essential for the port's economic well-being as its entire container throughput relies to approx. ⅓ on transhipment. This figures happened to be even much higher with approx. 50% a few years ago. However in the course of the recent crisis Hamburg has significantly lost transhipment volume to Rotterdam and Antwerp.

From the terminal’s point of view, all vessels with less than approx. 100 boxes to handle are critical anyhow with respect to profitability. However, in Hamburg almost $^{2}/_{3}$ of all terminal calls by feeder vessels are below that figure [3]!

1.3 Inland barge operation

Inland navigation is facing a dilemma as far as the hinterland transport of containers to and from sea ports is concerned. On the one hand there is a common understanding that its share in hinterland transport has to be substantially increased – for capacity and environmental reasons. On the other hand in sea ports inland waterway vessels have to berth at the facilities which are tailor made for serving the biggest container vessels sailing on the seven seas with a capacity of 13,000 TEU and even more. Hence the efficiency of the big gantry cranes is rather low while serving the small vessels. Most disadvantageous however is that the small vessels have to compete for a berth with the deep sea vessels. Not surprisingly inland navigation enjoys the last priority when it comes to berth allocation:

1st priority:	Deep sea vessels
2nd priority:	Feeder vessels
3rd priority:	Inland barges

Terminals have to act like that – not only for navigational reasons as giant container vessels are dependent on certain tidal windows. The simple reason is that inland navigation companies are not the customers of the terminals! Actually they do not even have a contractual relationship with the terminals (in transport terms) as they are in most cases only subcontracted by the ocean carrier. Hence nobody can expect from the terminals that they dispense with revenue generating berth occupancy provided by deep sea vessels in favour of inland barges which do not even contribute to the terminal's core revenue. Consequently in most cases no performance can be enforced by inland navigation which is only one mode (the smallest) of hinterland transport of the ocean carrier's boxes.

Inland barges suffer even more than feeder vessels. In major container ports there are many facilities where inland barges have to call at. E.g. Rotterdam has approx. 30 terminals and depots which are frequently served by inland barges. The average number of terminal calls per vessel is about 10 whereas in about 50 % of the calls only less than 6 containers are handled [4]! This kind of inefficient and not coordinated 'terminal hopping' is very time consuming and each delay at a single terminal results in incredible accumulated waiting time during the entire port stay. Not surprisingly only ⅓ of the time in port is used for productive loading/unloading [5].

In line with the presently reduced container volumes and less calls from ocean carriers in many sea ports the situation has been slightly eased in the recent past. However the ports of the ARA range (Amsterdam, Rotterdam, Antwerp) have already suffered very much in the not too distant past when inland navigation vessels had to wait several days for a berth at the terminals! In ports like Rotterdam where inland navigation has a share of more than 30 % in hinterland container transport [6] such delays have a substantial negative impact on the general logistic quality of the entire port. In Hamburg where inland navigation has still only a share of 2 % in hinterland container transport the inefficient operation has been identified as one of the major reasons for such a small share [7].

There have been already some Dutch and German studies on the problems of transhipment procedures for containers between inland navigation and deep sea vessels in sea ports [4] [5] [7]. One common result was that container handling for inland navigation and deep sea vessels should be separated from each other. In other words: Inland vessels should not call at the deep sea facilities any more.

Fig. 4: Enlargement of Delta Terminal in Rotterdam by new berths for feeder vessels and inland barges [8]

It is claimed that dedicated inland waterway berths have to be introduced at deep sea terminals. However most terminals do not have any shallow draught waterfront left where such berths could be meaningfully arranged. However switching existing and valuable deep sea quays to exclusive inland navigation berths with dedicated (smaller) gantry cranes does not pay off as such a measure would reduce revenue earning capacity (see above). Only at the Delta Terminal in Rotterdam some dedicated feeder and barge berths are constructed at a waterfront which has not been used before (see Fig. 4).

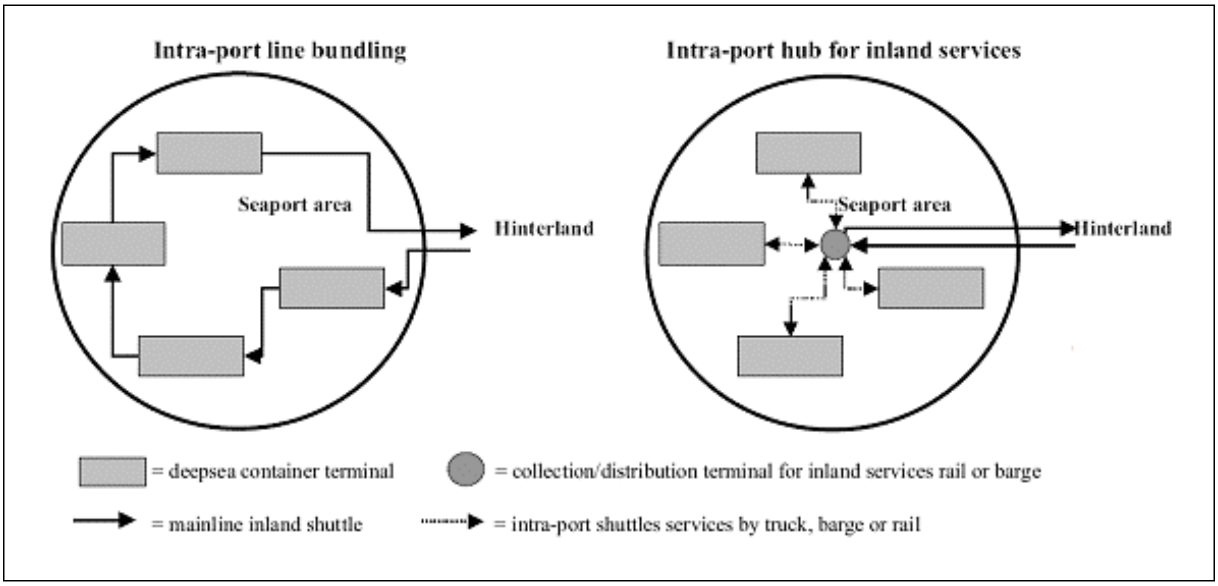

Fig. 5: Usual scheme of handling inland container barges within major container ports vs. an intra-port hub concept [9]

To spare the inland barges also the inefficient 'terminal hopping' the erection of a central and dedicated inland navigation terminal within a port, where all inland barges call only once, has also been proposed (see *Fig. 5*). However this would burden the most environmentally friendly mode of hinterland transport with the costs of two further quayside crane moves and one additional transport within the port (either on the water or even by truck). Hence the costs of inland navigation would not be attractive any more and the opposite of more waterborne container hinterland transport would be achieved. Hence increasing the share of inland navigation in hinterland transport of containers is really facing a dilemma in many major container ports.

2 State of the art

2.1 'Container Transferium'

The so-called 'Container Transferium' is a central inland navigation terminal which however is located outside the port. Initiated by the Port of Rotterdam this new barge terminal shall be constructed in Alblasserdam (60 km upstream of the Maasvlakte container area). The main purpose is to reduce container trucking on the A 15 motorway, which is the main road access to the Maasvlakte area. Within 3 years 200,000 TEU should be drawn annually from the road to the water. Beside its function as a branch terminal or extended gate for the large Maas-vlakte deep sea terminals the new facility is also intended to allow containers to be transferred from hinterland barge to dedicated shuttle barges which shall call only at one certain ocean terminal.

38 million Euro are going to be invested in the Transferium [10]. No matter whether the Transferium is used as an extended gate or as a transhipment point between hinterland and shuttle barges two additional crane moves and one shipment by shuttle barge have to be paid for. Although some ocean carriers have already signed (not binding) 'letters of support' it appears that is still not clear how the investment will pay off and who will actually pay for it.

Fig. 6: 'Container Transferium' near Rotterdam (source: Port of Rotterdam)

Hence a central inland navigation terminal where all inland waterway vessels are calling at but which can dispense with additional haulage within the port would be perfect. But how to dispense with the additional haulage? Solution: The entire terminal itself has to move! Hence the terminal has to be of floating type.

2.2 Hong Kong style midstream operation

Fig. 7: Unique midstream operation in Hong Kong

In Hong Kong ⅓ of the huge port's container throughput, which is still more than the total volume in Hamburg, relies on floating units serving deep sea vessels directly while laying at anchor (see Fig. 7)! These traditional but unique mid stream barges are equipped with their own cargo gear, but the handling method is far from being sophisticated. The A-frame derricks have a single beam just controlled by wires and are not even fitted with a spreader, but instead rely only on steel wires being fitted manually to the corner castings of the containers. In fact this is cargo handling technology from the 1950s and complies hardly with international port labour safety standards. Such midstream barges are only operating in Hong Kong (except a few in Angola). Not even in India they would comply with the local safety regulations. Quite apart from the health and safety issues related to such barges, they are not self-propelled (not even pushed but towed).

2.3 'AMSbarge'

To spare the terminals the use of their oversized crane equipment for box handling in waterborne hinterland traffic there was the idea to employ self sustained inland barges. Just 4 years ago a conventional but self sustained inland barge has been introduced in Amsterdam and is occasionally operated in Rotterdam as well. The 'Mercurius Amsterdam' (marketed as 'AMSbarge') is a typical inland waterway vessel which has been equipped with a standard shipboard crane [11] [12].

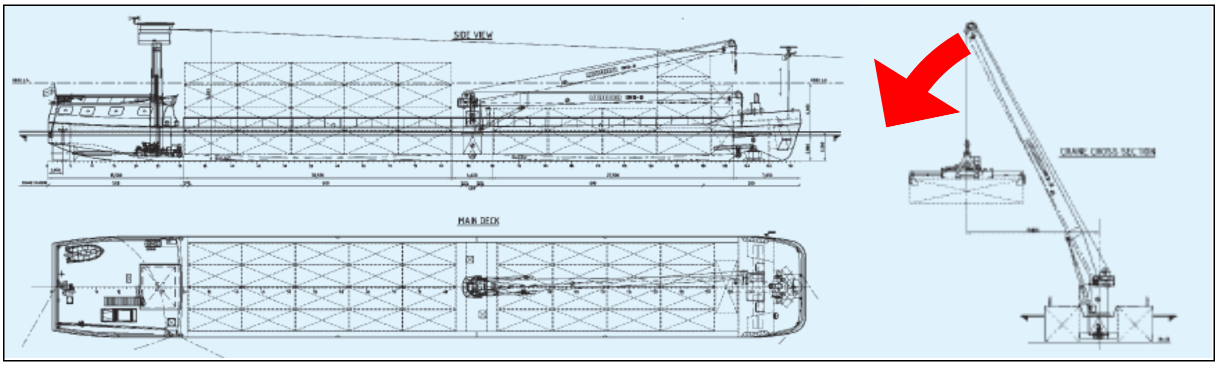

Fig. 8: "Mercurius Amsterdam" [11](modified by author)

This type of vessel represents some progress as its container crane allows for operation independently from quayside equipment. Its main purpose is to shuttle containers from inside the sea port to shippers and consignees just outside the port area that have their own water access (but no crane). As the vessel therefore has to pass through narrow canals and underneath low bridges it has to fully comply with the constraints of inland navigation. Consequently the concept suffers from some decisive handicaps:

Due to its slim beam only the weight of an automatic spreader (approx. 10 t) causes a heeling moment at maximum outreach of the crane (even without a container) that could jeopardize the stability of the entire vessel! Consequently the crane is not allowed to take several positions with a load under the hook (even without a spreader). Hence this type of vessel is a fairly workable concept just for transferring containers from sea ports to surrounding places, but although self propelled and theoretically self sustained (only to a certain extend), it is not suited for heavy duty self sustained container operations. Not surprisingly containers are still handled by terminal's gantry cranes when the vessel is berthed at deep sea terminals![4]

Due to the low height of the crane's outrigger boxes in the 3rd layer can only be handled in a certain order. E.g. boxes close to the crane's column have to be loaded last and discharged first which makes stowage planning very complicated.

Amsterdam is a port with locks and consequently has relatively low quay heights. In open tidewater ports quay heights are much higher (naturally at low tide). Under these conditions the crane driver is sitting far below the quay level and can not overview his operation on the terminal ground.

A floating terminal for inland navigation suited to the needs of European container ports should have sufficient container stowage capacity and should be firstly self-propelled and extremely manoeuvrable and secondly self sustained with a modern full scale cargo gear (without restrictions). These considerations have resulted into the design of a new type of intermodal harbour vessel.

[4] Information by Mr. Zimmermann, Managing Director, Mercurius Scheepvaart, April 2008

3 The 'Port Feeder Barge' concept

The internationally patented **Port Feeder Barge** is a self-propelled container pontoon with a capacity of 168 TEU (completely stowed on the weather deck), equipped with its own state-of-the-art heavy-duty container crane mounted on a high column. The crane is equipped with an automatic spreader, extendable from 20ft to 45ft, including a turning device. A telescopic over height frame is also carried on board. The barge is of double-ended configuration, intended to make it extremely flexible in connection with the sideward mounted crane. Due to the wide beam of the vessel no operational restrictions (stability) for the crane shall occur. The crane has a capacity of 40 tons under the spreader, at an outreach of 27 meters (maximum outreach: 29 m). The unique vessel is equipped with 2 electrically driven rudder propellers at each end in order to achieve excellent manoeuvrability and the same speed in both directions. Hence the vessel can e.g. easily turn on the spot. While half of the containers are secured by cell guides, the other half is not, enabling the vessel to carry containers in excess of 40ft length as well as any over-dimensional boxes or break bulk cargo. 14 reefer plugs allow for the over night stowage of electrically driven temperature controlled boxes.

The vessel shall fulfill the highest environmental standards. A diesel-electric engine plant with very low emissions (achieved by exhaust scrubbers, urea injection and filters) has been chosen to supply the power either for propulsion or crane operation. The vessel can be operated by a minimum crew of 3 whereas in total 6 persons can be accommodated in single cabins.

The key element of the worldwide unique **Port Feeder Barge** concept is its own full scale heavy duty container crane. While it looks like a standard shipboard crane, all its mechanical components have been especially designed for continuous operation – unlike standard shipboard cranes, which are designed for operation only every few weeks when the vessel is in port. Due to its nature, the **Port Feeder Barge** is continuously in port – seven days a week. Hence the load cycle requirements are even higher than for many quayside cranes, which has significant consequences on the layout of all mechanical components.

When berthed, the **Port Feeder Barge** is able, without being shifted along the quay, to load or discharge 84 TEU in three layers between the rails of typical quayside gantry cranes (see Fig. 11). This is more than sufficient, with a total loading capacity of 168 TEU. That is why the full outreach of the crane is not always needed. Berthing the vessel with the crane on the opposite side of the quay (see Fig. 10) would speed up crane operation as the turning time of the outrigger is minimised. The height of the crane column is sufficient to serve even high quays in open tidewater ports even at low tide while stacking the containers in several layers (or to serve even deep sea vessels directly, see Fig. 16). Due to its short length of 64 meters the **Port Feeder Barge** needs only a small gap between two deep sea vessels for self sustained operation at deep sea terminals (see Fig. 12).

The operation of the **Port Feeder Barge** is not limited to inside sea ports. As the hull is classified according to Germanischer Lloyd's class notification for seagoing vessels the operation in (sheltered) open waters off the coast is also possible which opens some interesting opportunities for additional employment.

Fig. 9: ***Port Feeder Barge*** *(computer rendering)*

Port Feeder Barge

Main Data

Type: .... self propelled, self sustained, double-ended container barge

Length o.a.: .... 63.90 m
Beam o.a.: .... 21.20 m
Height to main deck: .... 4.80 m
Max. draft (as harbour vessel): .... 3.10 m
Deadweight (as harbour vessel): .... 2,500 t
Gross tonnage: ....approx. 2,000 BRZ

Power generation: ....diesel-electric
Propulsion: ....2 x 2 electrical rudder propeller of 4 x 280 kW
Speed: .... 7 knots at 3.1 m draft

Class: .... GL ✠ 100 A5 K20 Barge
equipped for the carriage of containers, Solas II-2, Rule 19 ✠ MC Aut

Capacity: ....**168 TEU** (thereof 50% in cellguides), 14 reefer plugs
Crane: .... LIEBHERR CBW 49(39)/27(29) Litronic (49 t at 27 m outreach)
Spreader: .... automatic, telescopic, 6 flippers, turning device, overheight frame

Accommodation: ....6 persons (in single cabins)

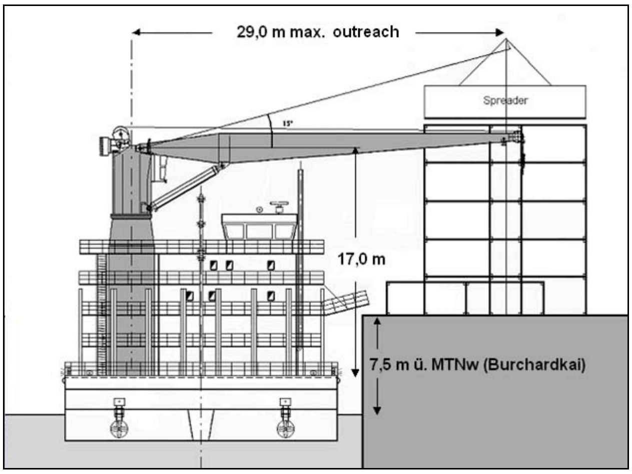

Fig. 10: PFB: Outreach of crane

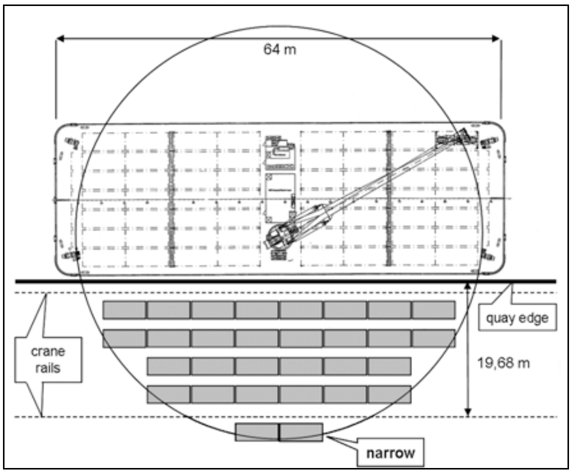

Fig. 11: PFB: Turning circle of crane

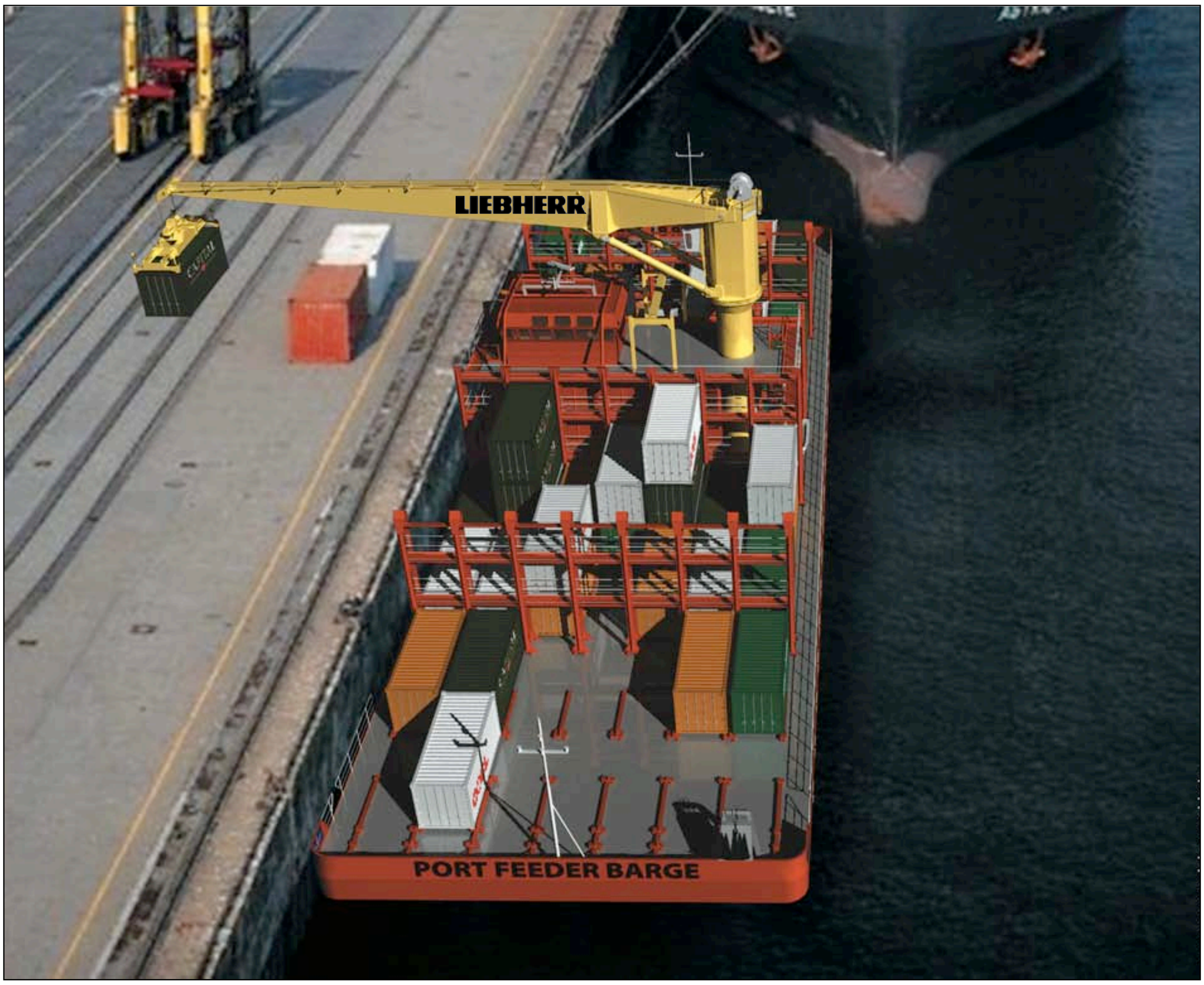

Fig. 12: ***Port Feeder Barge*** *is working independently from quayside equipment at a deep sea terminal requiring only a small gap between two deep sea vessels*

The design of the vessel has been developed by PORT FEEDER BARGE GmbH, Hamburg, in close cooperation with Wärtsilä Ship Design Germany GmbH, Hamburg (formerly: Schiffko, Hamburg).

3.1 Service patterns

Within the port of Hamburg the **Port Feeder Barge** shall offer a daily liner service (to be booked even for single boxes) connecting all the major waterside container facilities of the port with each other, including a dedicated berth to meet with the inland waterway vessels. During its daily round voyage throughout the port the **Port Feeder Barge** is collecting and distributing the containers from/for hinterland transport by inland navigation. Once a day, the **Port Feeder Barge** will call at a dedicated berth to meet with the inland barges where the containers will be exchanged ship-to-ship by the ship's own gear, independently from any terminal equipment. Not even a quay is required but the transhipment operation can take place somewhere midstream at the dolphins.

*Fig. 13: The **Port Feeder Barge** is serving an inland barge midstream (computer rendering)*

Konigs has analysed the reorganization of container barge services which consists of splitting existing services into a trunk line operation in the hinterland and collection/distribution operations in the sea port. It was generally concluded that these split services can substantially improve the competitiveness of barge hinterland transport in general although Konigs has based his calculations on a tariff of 95 € /TEU for distributing/collecting containers which includes 2 quayside crane handlings and the sailing costs of the feedering [4]. That exceeds by far the respective tariff of a **Port Feeder Barge**. Consequently such service model would very much benefit from using self sustained distribution/collection vessels which serve the hinterland vessels directly ship-to-ship (see Fig. 13) and shuttle the boxes to/from the final terminal where they are handled by the vessel's own gear as well. Instead of 3 moves/box being necessary by the costly quayside gantry cranes with any kind of 'Central Exchange Point', 'Barge Service Centres' or 'Multi Hub Terminal' model as

investigated by Konigs only 2 moves/box by the cheaper shipboard crane are needed with the **Port Feeder Barge** as the intra-port transport is already included.
If push barges are employed in hinterland transport the **Port Feeder Barge** could take them alongside during the round voyage throughout the sea port. That would further increase the capacity of the vessel and the necessary handlings could be further reduced to only 1 move/box by the vessel's own gear.

Such kind of operations will strengthen the competitiveness of inland navigation and could contribute to increase its share in hinterland transport. Employing one or more **Port Feeder Barges** as a 'floating terminal' is less costly and much quicker and easier to realise than the erection of comparable quay based facilities (not to mention that less parties have to be involved for approval).

Beside its purpose as a 'floating terminal' for inland navigation the **Port Feeder Barge** shall serve as a floating truck in the course of its daily round voyage throughout the port shuttling containers between all the various terminals. Hence container trucking on the roads within the port can be substantially reduced [13].

As the feeders are already big customers of the container trucking companies for intra-port haulage the **Port Feeder Barge** can replace trucking for collecting and distributing the containers. The **Port Feeder Barge** will offer a more competitive service than the trucks can do, especially for lots of many or overdimensional boxes (flats with overwidth/-height). Hence the **Port Feeder Barge** can be used by the feeders more intensively than the trucks at present enabling the feeders to concentrate more on the major terminals only, thus reducing the number of vessel shiftings, reducing their time in port and related costs, improving safety and increasing terminal and berth efficiency.

With a capacity of 49 t under the hook (40 t under the spreader) the **Port Feeder Barge** can also be employed as a floating crane for any kind of cargo other than containers.

3.2 Urban issues

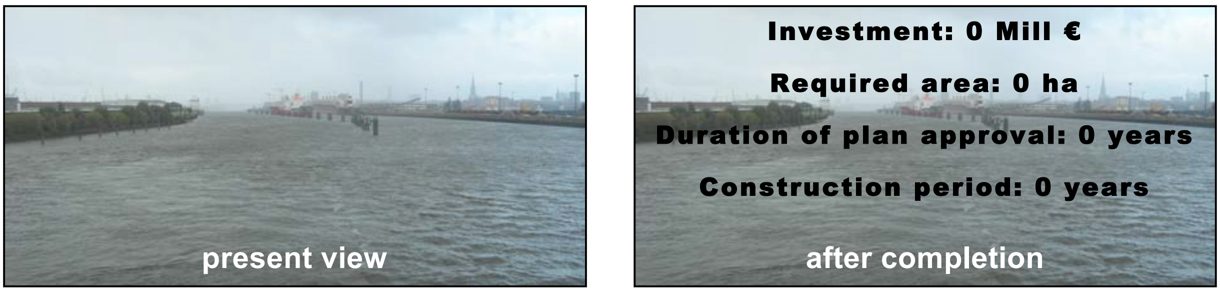

Fig. 14: Proposed location for a 'dedicated inland navigation container terminal' at the dolphins within the port of Hamburg making use of the ***Port Feeder Barge*** *concept*

Operating **Port Feeder Barges** is also beneficially affecting urban issues. Ports which may consider to improve their intermodal connectivity for inland navigation by heavy investments in dedicated terminal facilities could reconsider their strategy by evaluating the operation of **Port Feeder Barges** instead. With respect to investment, availability of land reserves, construction approval, flexibility and not to forget environmental and townscape issues a 'floating terminal' is much smarter than any land based facility (see Fig. 14). In addition it could be financed privately.

3.3 Emergency response

The **Port Feeder Barge** can also help to keep consequences of maritime averages at a minimum. When container vessels are grounded in coastal zones they mostly have to be lightered very quickly to set them afloat again in order to avoid further damage to the vessel, the environment and in extreme cases to sustain even the accessibility of the port at all. However it has honestly to be conceded that most container ports are not prepared for such situations and do not have suited floating cranes available (if any) which are able to quickly discharge big container vessels.

Fig. 15: Grounded panmax container vessel on Schelde river heading for Antwerp which could not be lightered quickly enough

Unlike some other heavy floating equipment, the barge can navigate in very shallow waters due to its light ship draught of only 1.2 meters. Despite its small size the **Port Feeder Barge** can e.g. lighter grounded container vessels even with more than panmax beam by working from both sides (see Fig. 16).

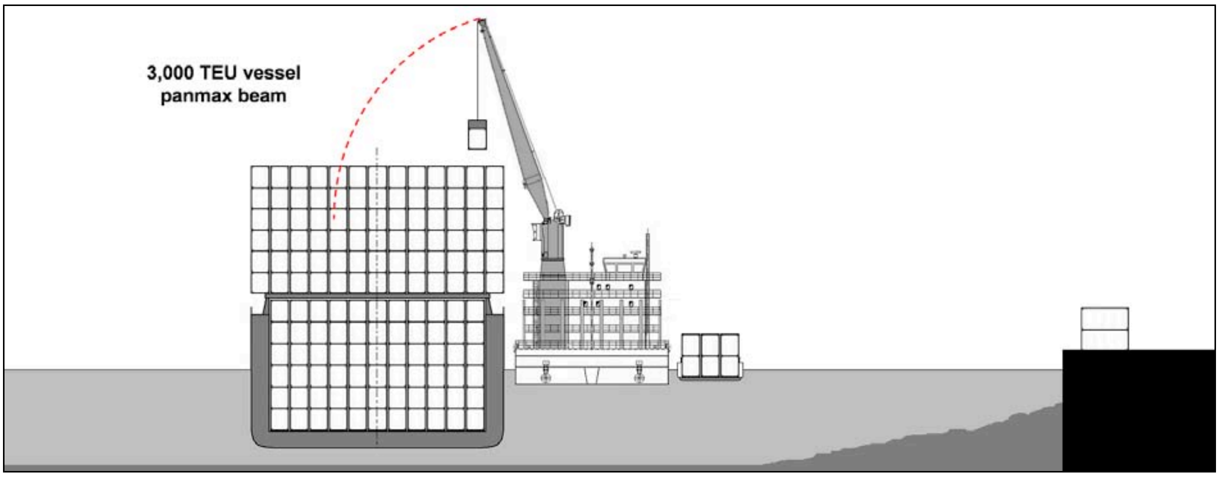

*Fig. 16: **Port Feeder Barge** employed as a floating terminal for deep sea vessels and/or for inland barges*

3.4 Option: LNG as fuel

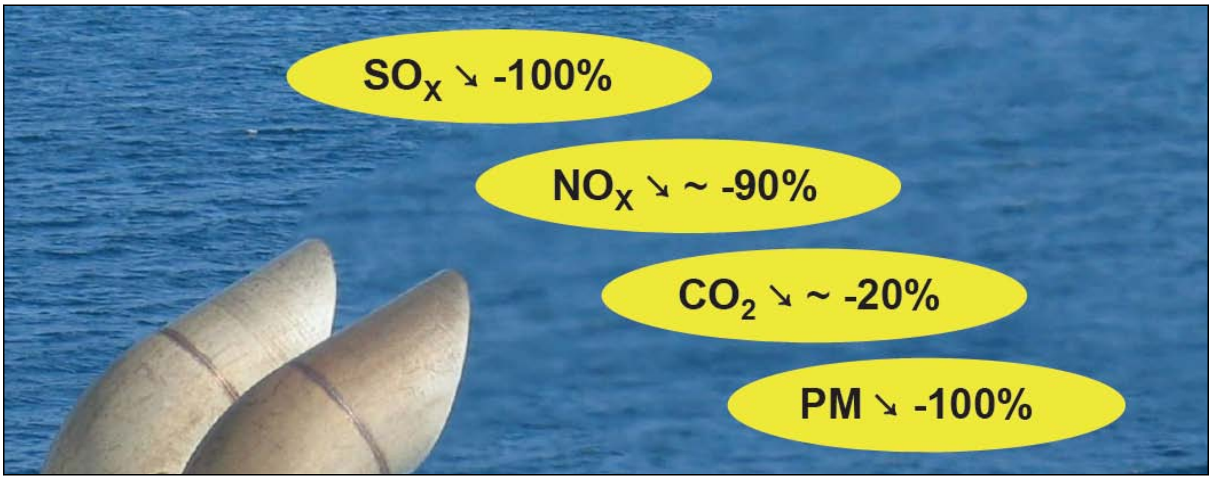

Fig. 17: Effects on emissions when using LNG as fuel (source: Flensburger Schiffbau Gesellschaft, 2010)

All costly measures to be taken to keep the exhaust emissions of the diesel-electric engine plant at the envisaged minimum (exhaust scrubbers, urea injection and filters) could be saved when choosing LNG as fuel (see Fig. 17). The **Port Feeder Barge** would be an ideal demonstrator for LNG as ship fuel:

- As a harbour vessel it does not rely on a network of bunkering stations. Only one facility is sufficient (firstly the vessel could even be supplied out of a LNG tank truck).

- Due to its pontoon type there is plenty of void space below the weather deck. Hence accommodation of the voluminous LNG tanks would not be a problem at all as it is the case with all other types of harbour vessels (see Fig. 18).

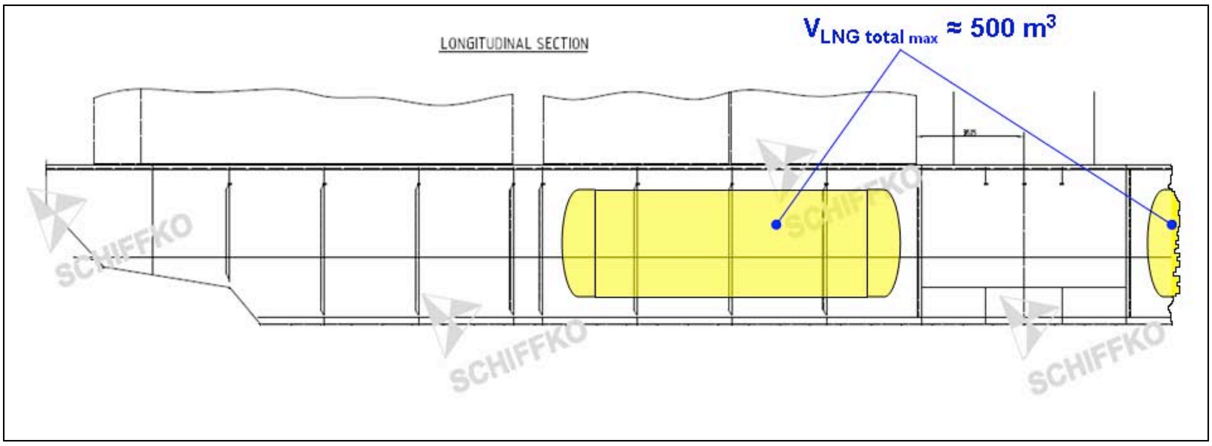

*Fig. 18: Possible accommodation of LNG tanks on board the **Port Feeder Barge***

4 Conclusion

As there is no doubt that container volumes will certainly recover in the future the present recession should be used to prepare for the next increase to avoid the already experienced bottleneck situations in ports and to reduce the environmental impact of transhipment procedures.

The **Port Feeder Barge** concept is a 'green logistic innovation' for sea ports (whose beneficial effects to the environment can even be further increased by using LNG as fuel) that could help …

- to shift container trucking within sea ports to the waterway,
- to ease feeder operation within multi terminal ports,
- to improve the intermodal connectivity of inland navigation within sea ports,
- to be prepared for grounded container vessels.

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