The Future of Intermodal Freight Transport
Operations, Design and Policy

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TRANSPORT ECONOMICS, MANAGEMENT AND POLICY

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8. A technical approach to the Agile Port System

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8.1 INTRODUCTION

Container ports are breaking points in the intermodal transport chain. To absorb differences in arrival and departure time and quantity between ocean flows and inland flows, often due to a lack of information about the next step of the journey, containers have to be stored on shore (Figure 8.1). This requires sufficient internal transport and stacking crane capacity to cope with peak demands (Kreutzberger 1999).

With average dwell-times per container of several days (for example six to eight days in US marine terminals depending on the location of the port; Vickerman 1999) and vessels becoming bigger and bigger (Figure 8.2), storage in container ports is demanding more and more space and driving ports to their spatial limits. As a result, there are endeavours to shift storage facilities from ocean harbours to inland facilities. Examples are the US Agile Port System proposal for large container flows, to be further

Figure 8.1 Terminal Burchardkai, HHLA, Hamburg, Germany
discussed in this chapter, as well as the European Commission (EC)-funded Asapp-One project for smaller container flows in urban areas (N.N. 2001).

8.2 OUTPLACING STORAGE FACILITIES FROM OCEAN HARBOURS: THE AGILE PORT SYSTEM

Some years ago a multi-year research project was launched by the US Transportation Command (USTRANSCOM), the US Maritime Administration (MARAD) and the Center for Commercial Deployment of Transport Technologies (CCDOT) resulting in a proposal, known as the Agile Port System (Vickerman 1999), to split a container port into an Efficient Marine Terminal (EMT) ashore and an Intermodal Interface Center (IIC) inland, connected by a dedicated railway line.

The idea behind the Agile Port System (Figure 8.3) is to:

- handle as many containers as possible between vessels and trains without storing them in the EMT;
- transport containers immediately between EMT and IIC by train;
- sort containers between trains according to their final destination, the IIC being favourably linked to several marine terminals in order to increase service frequency (Kreutzberger 1999);
8.3 ADDING EFFICIENCY TO REDUCED LAND REQUIREMENTS: THE EFFICIENT MARINE TERMINAL

The Efficient Marine Terminal as proposed by the US consortium operates like a conventional marine terminal, but features a rail interface instead of a conventional yard. Vessels are unloaded at the EMT and yard vehicles transport containers in much the same way as they are carried now (Figure 8.4), but the containers are then loaded directly onto trains in the yard. Some buffer storage would be provided in a separate area, but most of the containers would leave the terminal directly. The main idea behind the logistical concept of the EMT is to load and unload large vessels on a reduced area of land with minimal impact on the inland public traffic system and the environment (Avery 2000a).

In addition, the EMT concept developed by Noell Crane Systems is targeted on maximizing port productivity by transshipping boxes directly from vessel to trains and vice versa at the quay.

The proposed solution (Figure 8.5) features a combination of improved semi-automated ship-to-shore cranes (STS), semi-automated cantilevered

Sources: Vickerman (1999); Avery (2000a)

Figure 8.3 The Agile Port System: splitting marine container ports into two parts

- load and unload trucks which serve the region nearby, inland at the IIC.
rail-mounted gantry cranes (RMG) and a box mover based on rail-mounted automated shuttle cars driven by linear motor technology (LMTT), to be described in detail further below.

Drawing on its experience of the innovative quay cranes with lashing platform (Figure 8.6) in Hamburg (HHLA), the test site for gantry crane automation in Würzburg, and the LMTT pilot installations in Hamburg (Eurokai) and Würzburg, Noell improved the original EMT concept by incorporating the following features:

- Single trolley ship-to-shore cranes able to unload containers to a platform in the quayside portal, where the twist locks from deck containers can be removed.
- A conveyor to move containers from the lashing position on the platform to a second position underneath a RMG cantilever, which could be extended to provide additional buffer-space. The idea of
integrating a conveyor into a quay crane as a dynamic buffer for containers is not new. It was realized years ago by Matson Terminal, Los Angeles.

- RMGs that operate under the portal of the ship-to-shore cranes, covering for example four rail lanes and a three-lane wide box mover.
- Two extra service lanes under the lashing platform of the STS.

The big advantage of this concept is that yard transfer vehicles are not required, saving a great deal of machinery and labour, which, it should be remembered, is not particularly cheap in the Western world. When serving the vessel, one duty of the RMG would be to take containers from the platforms and place them on the linear motor-based transfer system or the rail cars on the shortest possible way and vice versa. The linear motor lanes could serve additional RMG loading and unloading along the trains as well as a buffer stack where this is required. The linear motor system would allow boxes being out of sequence to be held aside and shuffled without interrupting the ship-to-shore import–export cycle. Five to eight RMGs could service five ship-to-shore cranes between them (Avery 2000a).
8.4 BUNDLING OF RAIL-BOUND CONTAINER FLOWS INLAND: INNOVATIVE HUB TECHNOLOGY

Intermodal Interface Center

The Intermodal Interface Center as proposed by the US consortium operates like a conventional rail terminal, performing either rail transshipment (without using an efficient sorting facility) or train/truck transfer (Figure 8.7).

In addition, the IIC concept proposed by Noell Crane Systems is targeted on maximizing node productivity by featuring a combination of...
semi-automated cantilevered rail-mounted gantry cranes and again a box mover as it is to be used in the EMT. This innovative MegaHub technology, as it is known, was elaborated on behalf of Deutsche Bahn (German Railways) for bundling Continental container flows (Franke 1997) and the plan is to implement this technology near Hanover (Lehrte) in Germany (Figure 8.8).
MegaHub

The MegaHub production system for container trains has been developed for the transportation of container volumes that are currently considered too small to make it cost-effective for direct train carriage (Avery 2000b). The benefits of this system to the railway network have been described in the EU research project TERMINET (TERMINET Consortium 2000b).

Initially all containers are loaded onto the train, including those not scheduled for the train’s particular destination. These are then offloaded once the train has stopped at the MegaHub and loads from other trains intended for the first train’s specific destination are loaded on. The containers have to be loaded in groups according to destination, but shunting is not necessary.

Different proposals for the design of a MegaHub have been made in response to a design contest arranged by Deutsche Bahn in 1995 (Kortschak 1997; Fabel and Sarres 1997). The winner of the contest in technical and economical terms was the Noell MegaHub concept. Even though many years have passed, no technical alternative has been proposed since then.

At the MegaHub the actual transfer is undertaken on a surface covering an area as small as 730 m × 80 m, at a rate of up to ten ITU (intermodal transport units, either a container or swap body) per minute between dedicated trains. The storage capacity is a maximum of 270 ITU, but can be enlarged. Each transfer is carried out using electrically powered and semi-automated cantilevered yard gantry cranes (Figure 8.9) which span the transfer area and are able to lift to and from road vehicles, railway wagons, shuttle cars and the storage area.

The first MegaHub in Lehrte is planned to consist (in its initial state) of three semi-automated gantry cranes and about 12 fully automated shuttle cars controlled by an overall computer system. The transfer by crane is best done while the crane is travelling over very short distances. Long-distance travel is carried out by linear motor-driven shuttle cars, which can move along or across the sorting area (this is on one level only).

The outstanding feature of the MegaHub system is the modular construction using classic transfer technology. Put another way, if a very high performance level is not required, fewer gantry cranes and shuttle cars may be used. It is even possible to first store boxes flat at the location where, later, the runway for the pallets can be installed. For higher performance requirements it is possible to add extra cranes and to integrate the pallet system. The modular concept stands for economy even though the transport figures should not be too high when introducing this technology.
In January 2000, the results of a feasibility study (TERMINET Consortium 2000a) for the MegaHub concept, which formed part of the EC-funded TERMINET project (TERMINET Consortium 2000b) were presented to an expert hearing arranged by the German Social Democratic Party at the new Reichstagsgebäude in Berlin (Franke 2000). The focus was on the MegaHub’s main advantages: using transshipment to eliminate shunting, increasing handling speed and minimizing land area and cost per transfer.

When shunting is eliminated, generally the handling speed is increased remarkably (Figure 8.10). Handling six trains of 40 wagons with 64 Intermodal Transport Units (ITU) on each train takes five hours and 20 minutes using a shunting yard. By using a MegaHub with ten gantry cranes and 40 shuttle cars this can be reduced to just one hour and ten minutes. In the case of the shunting yard of Metz-Sablon, where most container trains of the ICF Quality Net service are shunted, this enables the number of ITU handled to be increased from 1120 per day (the maximum capacity of the existing shunting yard) to 2500 (the maximum capacity of the MegaHub using six gantry cranes and 15 pallet wagons).

The high performance of a MegaHub with up to ten gantry cranes and up to 45 pallets running together has been proven by simulation in two
independent doctoral theses: Dr Peter Meyer’s at the University of Hanover (Meyer 1999) and that of Dr Knut Alicke at the University of Karlsruhe (Alicke 1999).

The cost savings are equally impressive (Figure 8.11). In the case of Metz the operational cost per move range from €5.50 (three shifts, 870 000 visits...
per year) to €7.75 (one shift, 290,000 visits per year) with minimum personnel required. By comparison, the cost of handling 700 wagons per day (1.6 ITU per wagon) in the existing shunting yard at Metz in France is estimated to be €20 per ITU.

As far as total costs are concerned, a MegaHub in Lehrte (ten gantry cranes, 40 pallet wagons) able to handle 3600 wagons carrying 5760 ITU per day is estimated to require an investment of €105 million, of which €60 million is for superstructure. The cost of shunting infrastructure to handle the same throughput at the Munich Nord One facility was €250 million.

Aside from the impressive cost savings, perhaps the MegaHub’s greatest advantage for the future is the minimal amount of land required. Taking the Lehrte–Munich Nord example again, the Munich site needs 130 ha on which to handle 3600 wagons per day, compared with just 10 ha for a MegaHub.

8.5 HIGH-CAPACITY BOX MOVER FOR COLLECTION AND DISTRIBUTION ALONG THE TRAINS

Part of the Efficient Marine Terminal as well as of the Intermodal Interface Center (MegaHub) is a horizontal transport system for the sorting of boxes along the trains featuring linear motor-based transfer technology. Due to heavy obstruction, there would be no efficient container handling possible without such a horizontal transport system when loading and unloading trains by several gantry cranes using the same track.

Linear Motor-Based Transfer Technology (LMTT)

Generally the fully automated horizontal transport system consists of a system of tracks running parallel and at right angles to one another. Fully automatic shuttle cars are conducted lengthwise and crosswise along these tracks (Figure 8.12). What makes the system so attractive for applications in container terminals (Franke 2000) is the wagon’s ability to turn at right angles by moving the wheels by 90° instead of turning the whole wagon.

The shuttle cars are rail-mounted and bi-directional (straight ahead and sideways). They comprise a base frame and a loading platform that is capable of carrying loads up to 41 tonnes, which may well be increased to 54 tonnes for twin-lift operation. They are also equipped with double wheel sets that can be rotated 90° for the carrying and guiding functions. In addition, permanent magnet strips have been installed for the transmission of the driving power (Figure 8.13). The units for drive (linear motors) and
position detection are integrated into the runway. The control system is stationary.

The runway may consist of ordinary UIC 60 rails, mounted on steel twin sleepers. To make it possible to turn the wheel sets (of the shuttle cars), a circular steel surface with transverse guides has been fitted at the crossing points, that is, the intersections of the longitudinal and transverse travelling rails (Figure 8.12).

**Figure 8.12** LMTT pallet wagon propelled by electromagnetic force

**Figure 8.13** LMTT – Position detection system
A major advantage is that the chassis does not need an engine, brakes, gears, a Programmable Logic Control (PLC) or sensors. The shuttle cars are driven by means of contact-free linear synchronous motors, which are distributed over the track according to the requirement of driving force. They act on the magnets located on the underside of the shuttle cars. It is possible to set a variable speed by means of a mobile electromagnetic field, generated using a frequency converter. A contact-free actual position detection system (Hall sensors) is integrated into the runway and responds to the individual magnets located on the shuttle cars. This enables the absolute position of the shuttle car to be determined and supplies the input values required to ensure that the linear drives are supplied with power and switched over in the correct order.

The shuttle cars move at 3 m/s with an acceleration of 0.3 m/s\(^2\) and can be positioned with an accuracy of \(\pm 3\) mm. With so few moving parts, maintenance costs are kept to an absolute minimum and no fossil fuel is required (Bauer 1998).

The linear motor-driven transfer technology was initially developed with funding from the German Ministry of Research, BMBF (Consortium 1997). Between 1995 and 1998, test and demonstration plants (on a scale of 1:1) were set up at the Port of Hamburg, Eurokai (Wölper and Huth 1997), at the headquarters of Noell Crane Systems GmbH in Würzburg (both in Germany) and on the plant grounds of Noell Crane Systems (China) Ltd. in Xiamen.

**Simulation of the Box Mover Based on LMTT**

Each EMT (Figure 8.5) and MegaHub (Figures 8.8, 8.14), features two runways for longitudinal travel in parallel to the trains: one runway for each direction, plus one transfer lane between with access from both runways by a ‘sidewards step’ of a shuttle car. The transfer lane is also used for parking and loading and unloading of the shuttle cars by the gantry cranes. Each of these box movers is no wider than 13 m and about 700 m long.

Of course it is of high importance to know how many shuttle cars are necessary to fulfil given transport requirements and whether there might be deadlocks or not.

The modelling of the box mover as well as the simulation was done by using a version of SCUSY (Simulation von Containerumschlag-Systemen) software, which was developed by the ISL (Institut für Seeverkehrswirtschaft und Logistik) in Bremerhaven. This software was upgraded by adding an LMTT software module. This version of SCUSY enables the programmer to design the layout of the horizontal transport system easily by choosing from a software library of standardized runway modules (uni- or bi-directional,
longitudinal or transverse, crossings) which may be further specified to a certain extent. It is important to say that the LMTT software module features traffic regulations at crossings as well as distance regulations between vehicles following each other, while taking into consideration realistic kinematics and time requirements for positioning of the vehicles.

The simulation (duration $= 100$ min) was based on the following assumptions:

- Transshipment of boxes between six trains, each of them being 700 m long.
- Random distribution of boxes between trains.
- Sequential entry and exit of trains are unconsidered.
- Layout of the box mover (700 m $\times$ 13 m) as described above (Figure 8.15).
- Access to loading or unloading position by shuttle cars only from one of the two runways possible (no trespassing).
Shuttle cars dedicated to selected transport relations.
No optimization of empty run of shuttle cars.
Geometry and kinematics of the shuttle cars derived from the MegaHub Lehrte project.
Fixed length of work area per (gantry) crane is 700 m/no. of cranes (see Meyer 1999; Alicke 1999 for variable length of work areas).
No obstruction by neighbouring cranes (see Meyer 1999 for obstruction by neighbouring cranes).
Geometry and kinematics of the gantry cranes derived from the MegaHub Lehrte project.
Transport requirement = number of visits per time unit (= boxes/100 min).
Differentiation between direct and indirect (via box mover) transshipments.
Number of visits = number of direct + number of indirect transshipments.
Number of direct transshipments = 38 = approx. no. of visits / number of cranes (see Alicke 1999).
Number of cranes and number of shuttle cars are subject to change.

The outcome of the simulations is condensed in Figure 8.16, which shows the relation between transport requirements (boxes to be transshipped between trains within 100 min) and number of cranes and shuttle cars to do the job.
Based on the assumptions above it is possible to do a maximum of approximately 360 ( = 6 × 60) direct and indirect transshipments between six trains by operating ten gantry cranes, which means to completely inter-change boxes between trains having a capacity of 60 boxes each within 100 minutes.

By doing maximum performance 360 (1–1/10) = 324 boxes have to be moved by 40 shuttle cars. As a rule it can be said that four shuttle cars are needed to serve one gantry crane in such a MegaHub application.

8.6 CONCLUSIONS

In order to overcome spatial limits in marine container terminals there is a demand to split ports into an Efficient Marine Terminal (EMT) part ashore and an Intermodal Interface Center (IIC) inland, both connected by a dedicated railway line (Agile Port System).

By decoupling vessel- and train-side container handling at the EMT there is a technical solution available to transship containers between vessel and train and vice versa directly at the quay without a loss in performance. As soon as trains are loaded, import containers may be transferred by rail to the IIC. There they will be rearranged between trains according to their final destination or transferred to trucks for distribution. Export containers will be dealt with accordingly in the opposite direction. Instead of storing empties and import boxes at the sea terminal these boxes may be stored near the customer at the begin or end terminals inland, thus contributing to their small margins.

The IIC can be realized by using the Noell MegaHub technology being developed for an inland hub to be installed in Hanover (Lehrte), Germany, as it is planned by DB. In such a MegaHub it will be possible to transship up to 360 boxes between trains within only 100 minutes. Other locations where the MegaHub technology would be very suited for implementation are so-called gateway terminals near Zurich (Limmattal) and Basel to be realized by SBB (N.N. 2003a; N.N. 2003b).

REFERENCES


A technical approach to the Agile Port System