# Container Terminals in River Ports


**Milosav Georgijević**
Professor
University of Novi sad
Faculty of Technical Sciences

**Nenad Zrnić**
Assistant Professor
University of Belgrade
Faculty of Mechanical Engineering



*This paper deals with some problems concerning development concepts and equipment of container terminals in river ports, especially for Serbian ports located on river Danube. Paper discusses comparative data concerning transshipment and flow of containers in selected relevant European ports. The research focuses on the development of Serbian container terminals as parts of logistic systems and gives the basic concepts that should be the basis for river ports terminals in future. Results of simulation model of terminal are presented for two developed concepts terminals. The paper presents the analysis of technical parameters of quayside container crane suitable for Serbian river terminals as a principal subsystem in the whole terminal system, and also gives the proposal for crane's structure, kinematics of reeving, lifting capacity and some preliminary control tests.*



***Keywords:*** *containers, river port terminals, transhipment, quayside container cranes.*


## 1. INTRODUCTION

Containers are the main type of equipment used in intermodal transport, particularly when one of the modes of transportation is by ship, and they exist in present shape almost last 50 years. The usage of containers shows the complementarity between freight transportation modes by offering a higher fluidity to movements and standardization of loads. One of the keys to the success of the container is that the International Standard Organization (ISO) very early on established base dimensions (between 1968 and 1970), figure 1. The most common ISO containers are 8 ft (2.438 m) wide by 8 ft high, and are either 20 ft (6.06 m) or 40 ft (12.19 m) long. Other most common lengths are 45 ft (13.716 m), 48 ft (14.63 m), and 53 ft (16.154 m), although other lengths exists, e.g. 35 ft containers (Container Terminal Salzburg – Austria). In the USA longer containers are frequently used and the domestic 53 ft container is widely used.

**Figure 1. Standard ISO container**

Last year was announced an EU proposal for a bigger container which length should be 15 m and 40 t grievance weight, because there is evident rationale to use largest container size possible.


Received: September 2006, Accepted: December 2006



*Correspondence to:* Dr Milosav Georgijević, Professor
University of Novi Sad, Faculty of Technical Sciences,
Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia
E-mail: georgije@uns.ns.ac.yu


Due to the problems of stacking EU pallets in ISO containers, Europeans have promoted 15 years ago containers for inland transportation, which are wider than ISO containers, but have the fittings at the same place as ISO containers that enables the same way of handling, figure 2. These containers are innovated and their legs can be put in stowed position that enables simplification of loading and unloading procedure at locations without corresponding unloading machinery, wherewith is expedited the idea of intermodalism "from door-to-door".

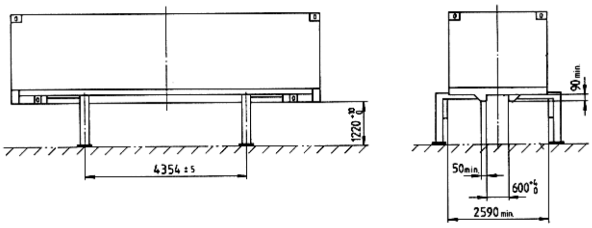


**Figure 2. EN container**

Containerization is a major component of intermodal transportation, international commerce, and an important element of the innovations in logistics that revolutionized freight handling in the 20th century. Worldwide container trade is growing at about 9.5% annual rate, and the US rate is around 6%. It is anticipated that the growth in containerized trade continues as more and more cargo are transferred from break-bulk to containers. By 2010, it is expected that 90% of all liner freight will be shipped in containers. Every major port is expected to double and possibly triple its cargo by 2020 [1]. World container traffic in millions of TEU is presented in figure 3.

Nowadays we have ships with capacities of the order 8,000 to 10,000 TEU, or even more that imposes permanent analysis in order to improve methods of containers handling and transshipment. Some of the biggest recently built container ships are Gudrun Maersk (7,500-9,500 TEU, Jun 2005), MSC Pamela (9,178 TEU, Jul 2005), Cosco Guanzhou (9,449 TEU, Feb 2006), and L203 Emma Maersk (8,000+~13,000

TEU, Sep 2006). In years to come, the limit will be Suezmax ship with 12,000 TEU. The next step will be MalaccaMax ship with 18,000 TEU, and may be expected within the next decade. A port must be planned to satisfy prompt accommodation of ships with minimum waiting time in port, and with maximum use of berth facilities, including cranes that requires permanent innovations.

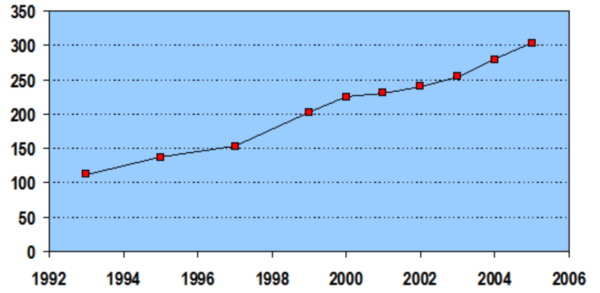


**Figure 3. World container traffic in millions of TEU**

Ships which are transporting containers in river waterways have capacities limited by their sea-gauge. Their capacities are from 800 to 1,500 t. These ships (or barges) enable stacking 3 containers abeam and carry up to 100 containers. By grouping and using push boat with up to 4 pushed barges (combination 2×2), the capacity of transport is increased to 500 TEU. Depending on the category of waterway the following combinations occur: 2×2, 3×2, or even 3×3 barges. In the region of river Rhine where the container transportation is more developed than in Danube region, over the years are used containers ships with 6 containers abeam and 3 to 4 containers stacked on top of each other, i.e. up to 4 units high, giving the capacity of 500 TEU.

Equipment for containers transshipment in river port terminals, also as in seaport terminals, consists of quayside container cranes for servicing ships, and other storage transshipment facilities. Storage transshipment facilities are basically the same as for seaports, and comprise mostly gantry cranes with manual control (RMG-Rail Mounted Gantry crane, servicing railway terminal), mobile cranes (RTG-Rubber Tire Gantry crane, straddle carrier), fork-lifters and reach-stackers. For transshipment from ships and barges to quay are also used quay cranes, but with different tasks and performances comparing to seaports. Quayside container cranes in river ports are servicing mostly storage, and have wider gage and active backreach (on the land side, LS). Their outreach (on water side, WS) is up to 30 m depending on the way of servicing ships and barges. Servicing the storage requires that motion of gantry-portal frame is operational with higher speeds of heavy construction of crane (more than 300 t), and with antisway control system that enables faster positioning of load. The mentioned requirement for operational motion of crane stipulates particular design of hoisting mechanism that makes these machines as biggest investment in port (costs from 3 up to 4 mill €) very specific.

## 2. EU WATERWAYS AND CONTAINERS FLOWS

Europe's transport policy has been characterized by liberalization and harmonization over the years. Globalization and concept of wider Europe create further challenges. Europe's transport system needs to be optimized by means of advanced logistics solutions [2].

The annual number of containers transshipped in Northern Sea ports is measured in millions of TEU, i.e. in 2005 for the port of Rotterdam 9,286,756 TEU, Antwerp 6,488,000 TEU, Hamburg 8,088,000 EU, with the trend of increase by 10%. Direct comparison of the necessary investment costs shows that one euro invested in waterway releases the same effect like 1.83 euros for the road construction or even 6.57 in the railway system invested euro, for 1,000 good metric tons per kilometer. Also, external cost for 1,000 metric tons per kilometer are higher 3.5 time for railroads transport, and 1.5 times for railways transport in comparison with river transportation by ships.

The port of Duisburg as the biggest in EU river waterway realizes currently transshipment of containerized freight of about 3 millions of tons. Figure 4 shows comparison between waterway and railway transportation.

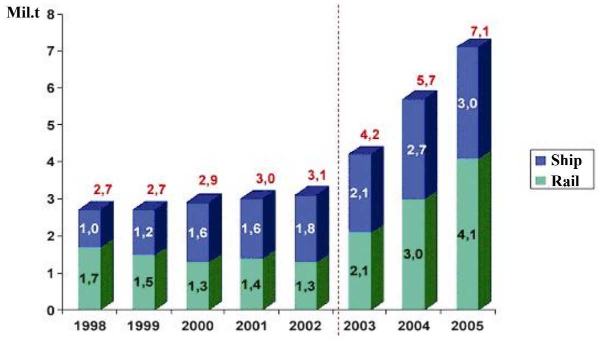


**Figure 4. Flow of goods in Port of Duisburg**

Unfortunately, the lion's share of mentioned containers has final destination in the fairway of Rhine, while the minor part is transferred on the river Mein, Channel and Danube. For Serbia the most interesting waterway is Danube and freight flow from the direction of Constantza (Black Sea) due to the renaissance of this port. Figure 5 presents transshipment of goods in some Danube ports.

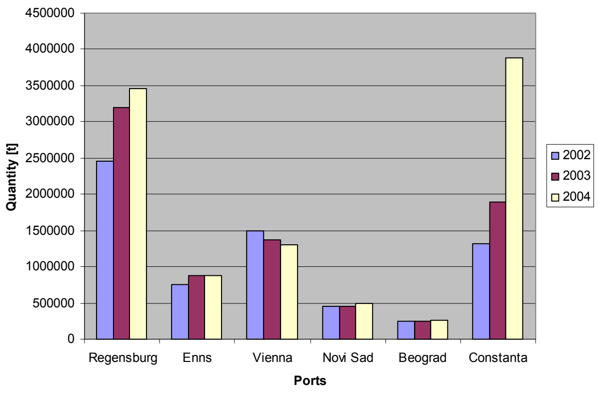


**Figure 5. Transshipment of goods in Danube ports**

Data for transshipment of containers in before mentioned ports is presented in figure 11, while the number of TEU has to be multiplied by 100 for ports Enns, Vienna and Constantza.

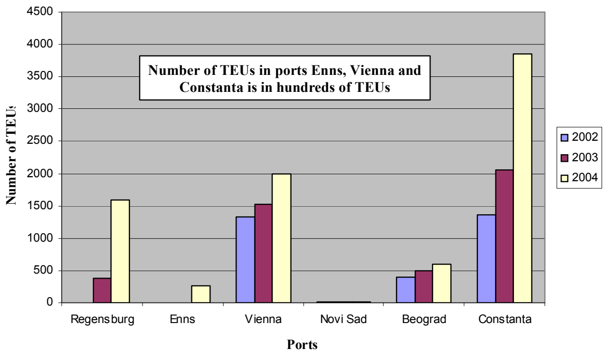


**Figure 6. Transshipment of containers in Danube ports**

Table 1 shows the parameters of containers transshipment in Austrian Danube ports for 2005. By comparing these date with ones shown in figure 6, it is conclusive that the tendency of growth is more than 10%. It is interesting to mention that container terminal in port of Enns (nearby Linz) is relatively new (since 1993) with the total capacity of 250,000 TEU and with the transshipment plan of 150,000 TEU for 2006. Unfortunately, the current situation in river ports, as logistic centers in intermodal transport chains, is that only minor part of containers transshipment is realized by ships.

**Table 1. Transshipment of containers for Austrian Danube ports**

| Container terminal | Transshipment in TEU for 2005 |
|---|---|
| Vienna | 225,000 |
| Krems | 40,000 |
| Linz | 167,000 |
| Enns | 130,000 |

## 3. CAPABILITIES OF SERBIA

Turnover of goods and economic growth of Serbia were much higher up to 1990 than it was in the last decade of XX century. At that time the number of containers was higher and even some types of containers where manufactured in Serbian factories (nowadays 26% of all containers in traffic originate from China, and about 85% of the world's containers are made in China). Nowadays we can expect the increase of containers traffic in Serbia and the perception of future development can be observed through analysis of data in goods traffic, figures 7,8.

For the estimation of development of containerization we should make an independent analysis of trends for classes of goods in container shipping, because general estimation of economic growth or number of containers originated from China can give false conclusion. It is conclusive from figure 8 that Serbia has significant increase of processed products.

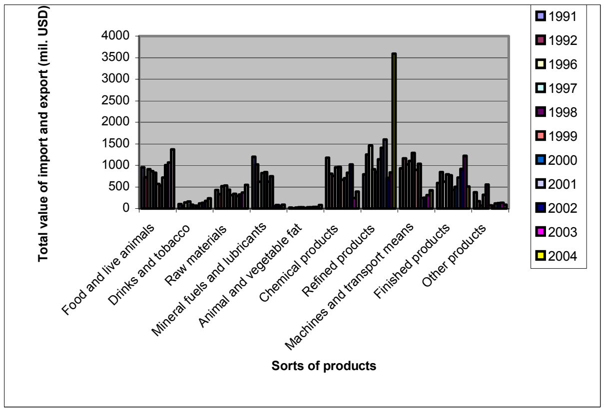


**Figure 7. Turnover of goods for some classes of products in Serbia**

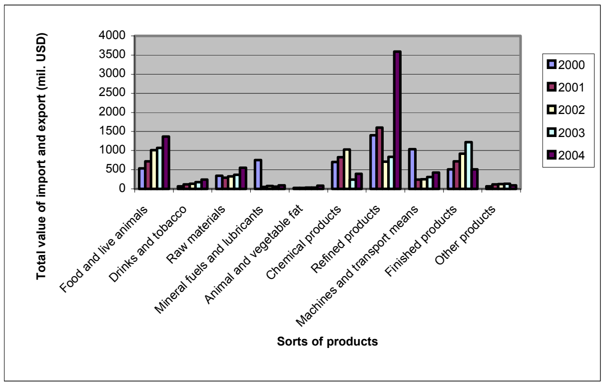


**Figure 8. Import and export data for Serbia**

## 4. CONTAINER TERMINALS IN SERBIA

Except the railway container terminal in Belgrade, there is no place in Serbia that can be treated in rigorous sense as container terminal. Port Belgrade has a completed container terminal, equipped for reloading all types of containers with capacity of 12,000 TEU per year. This fact makes the estimation of container traffic more difficult and responsible. Tendency to have a big terminal as distributive center is probably wrong. In EU there are a number of trends, some of which are contradictory. On the one hand, centralization of logistics organization and regional distribution centers is taking place, and, on the other, decentralization is emerging in the light of saturation on the European roads, enabling quick response from local warehouses or buffer storages to customer requirements. At first instance it is sensibly to set a hypothesis concerning the necessity of having railway terminal in Subotica, intermodal terminals in Novi Sad and Pančevo, and railway terminal in Niš. The explanation is found in geographic position of mentioned towns, Danube waterway link, and railway and roadway intersections.

Intermodal centers located on the Danube waterway should have adequate areas for cleaning and repairing containers and recertification of container's correctness. This is service industry where this region has advantage due to the cheap labor force. Center for reparation and further distribution of cleaned and recertificated container could have about 1,000 up to 2,000 TEU which can be redistributed in region, having in mind that the Port of Rotterdam has about 20% of empty containers in traffic.

## 5. TERMINAL CONCEPTS

Container terminal presents the logistic system and the system approach has to be used in order to select its concept, where the variables of the system are: disposable area, technical parameters of quay crane, possibility of reload from boat to boat (barge), length of backreach and other machinery working in storage (including technical parameters). System parameters like turnover of containers and technical parameters have to be considered with estimation of future development (10 to 20 years) [6].

In accordance with discussed facts for initial dimensions of terminal is adopted area 100×100 $m^2$, with plant for repairing containers, and without office and custom buildings. Figures 9 and 10 show examples of simulation model for container terminal with quayside crane (gage is 25 m), and this space is used for servicing wagons (3 tracks), trucks (3 transport routes), and potentially transitional yard storage as a preparation for loading and unloading. Transport routes are also used for communication with storage by straddle carrier (figure 9) and telescopic reach stacker (figure 10). Container terminal shown in figure 9 has storage capacity of 683 TEU and consists of one quay crane and one straddle carries with standard performances.

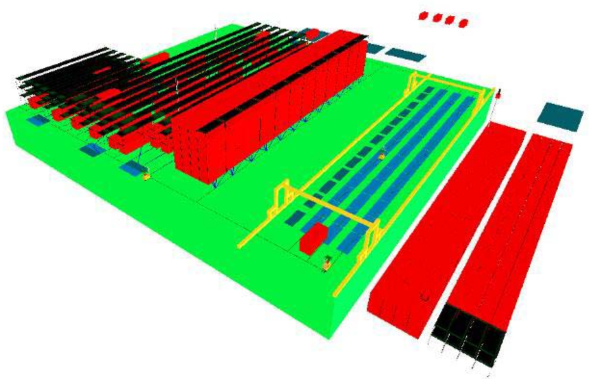

**Figure 16. Simulation model of terminal with straddle carrier in storage (software Enterprise Dynamics)**

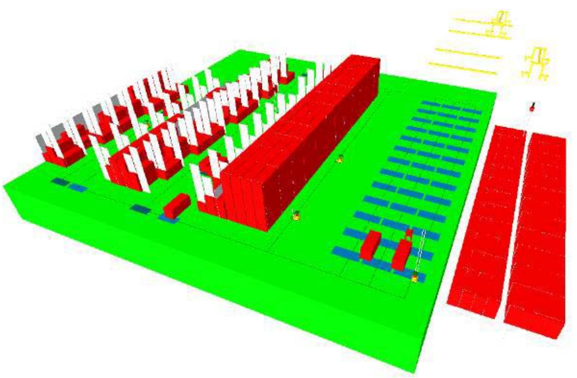

**Figure 17. Simulation model of terminal with telescopic reach stacker (software Enterprise Dynamics)**

Container terminal shown in figure 10 has storage capacity of 720 TEU, whereof at least 120 should be unfilled, and consist of one quay crane and telescopic reach stacker with standard performances. Dimensions of outreach and backreach are 25 m that enables transshipment from ship to ship, and on landside is possible stacking of 4 rows of containers alongside rail track and up to 5 containers aloft. Hoisting velocity is up to 1 m/s, while trolley and crane velocities are up to 2 m/s.

## 6. QUAYSIDE CONCTAINER CRANES

The previous analysis and system approach enables defining corresponding technical performances of system and equipment and leads to the necessity of defining structural solutions. Quay crane is the key subsystem that impose requirement towards other subsystems in the container terminal system [7]. Advantage of these cranes is motion in both directions of horizontal plane that requires specific hoisting drive with mechanical damping of container sway during motion and positioning. According to the experience from seaport terminal where hoisting unit has normally 8 inclined arms of mounted ropes, for cranes operating in river port terminals the required number of inclined arms is 16 in order to achieve antisway effect in both horizontal directions of motion, as shown in figure 11. At that is used for trolley type the heaviest self-driven construction, i.e. Machinery-On-Trolley (MOT) with the main hoist and trolley drives on board [8]. This construction can be rotational upon special request that makes it more complex. Total power of hoisting electromotor is up to 300 kW with installed frequency regulation of number of revolutions change, and with two hoisting speeds, one for container in other for empty spreader in diapason 2:1.

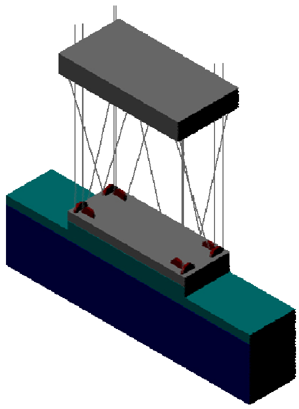

**Figure 11. Kinematics of ropes for hoisting mechanism**

## 7. LIFTING CAPACITIES OF CONTAINER CRANES

Maximum gross weight of ISO containers is 30,5 t requires lifting capacity of 40t, but the future demands for increasing gross weight will require lifting capacity of 50 t, or even 55 t. Hence the gross weight for the majority of containers is less than the maximum one, analysis of German Danube river ports show that the gross weight of containers in previous period was about 13.5 t/TEU. It is conclusive that quay cranes should be designed according to expected spectrum of loads and service life. At that spectrum of loads can be classified as following: up to 10 t, for hoisting of empty spreder, up to 30 t for mean value of containers gross weight, up to 40 t for maximum containers gross weight according to existing standard, up to 55 t for future maximum containers gross weight in new standard [4, 5].

Cross sections of gantry structure can be box, truss or combination of previous two solutions. Main girders are single or double. Some of realized constructions are replications of quayside cranes in seaports. But having in mind individuality of quay cranes in river ports it is reasonable to believe that they should resemble container cranes in railways terminal or in seaport storage. Figures 12 and 13 represent examples of realized constructions. Figure 12 shows double girder crane with box sections, where the current distance between main girders is about 13 m, but should be 16 m for expected dimensions of containers in future. Outreach has to be up to 25 m in order to service two ships (ship-barge). Figure 13 presents the construction with 3D truss main girder (triangular or rectangular shape) and with rotating trolley.

**Figure 12. Quayside container crane with box sections**

**Figure 13. Quayside container crane with 3D truss girder**

Having in mind the fact that trolley width for lightweight (comparing with solution in figure 12) structural solution shown in figure 13 is up to 6 m, it is conclusive that such solution is more preferable, but its shortcoming is found in high welding costs. Lightweight structure has positive effects because crane's motion is a part of working cycle. Possible problems of crane skewing due to the effects of structural stiffness have to be solved by adequate control of portal motion. For these crane are used electronic anti-pendulum systems that enables transferring load smoothly, quickly and precisely (± 5 cm) to their destinations, like Siemens HIPAC-TOUCHMATIC (Highly Intelligent Pendulum and Automatic Control), or similar systems. The touch-screen operator interface makes sway control and automation systems easy to use, and the result is increased turnover of full or semiautomated crane. Kinematics of ropes reeving imposes the value of period of oscillation (in horizontal directions) and it is reasonable to believe that the adaptive method of control is suitable for implementation [3]. Figure 14 shows the first control tests that will be further improved in order to obtain dynamic factors and spectrum of loading by simulation.

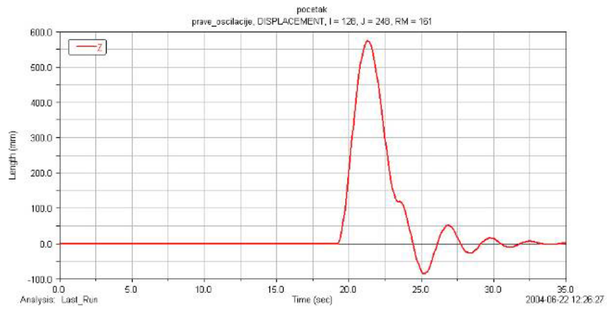


**Figure 14. Control tests for container crane**

## 8. CONCLUSION

Inadequately defined strategy of economic development of Serbia and neighbor countries is a constraint for more precise estimation of development of container transport, including river transport. Based on available data it follows:

- Upward trend of Serbian global export and import cannot be the only criterion for estimation of containers increase and necessity of building up river container terminals,
- Analysis of export and import for some groups of products can be trustworthy for making the decision of building up river terminals as constitutive part of logistic centers in Danube ports in Belgrade and Novi Sad,
- Container terminals must contain sections for repairing and certification of containers, because this function can be dominant in the first years.

Based on global tendency of world's containerization increase by 10%, as well as increase of transshipped containers in some Danube ports by 20%, it is useful to make the concept of modular development of container terminals by offering:

- Container terminal with area $100 \times 100\ m^2$ and capacity of about 700 TEU,
- Container terminal with area $100 \times 200\ m^2$ and capacity of about 1700 TEU,
- For further development of terminal is suitable to have are of more 10 hectares.

Equipment for reloading containers impose requirement to have one quayside crane with lifting capacity of 50 t, for forthcoming containers with increased gross weight comparing with actual ones defined by ISO. The main performances of quay cranes should be:

- Outreach up to 25 m in order to service two ships (transshipment between ship and barge),
- Working speeds at least 2 m/s that is in according with requirements of river port users,
- Backreach is necessary to service storage.

During researches done for the Serbian factory “GOŠA” as possible future manufacturer of first ever built container crane in Serbia, authors of this paper have analysed numerous technical solutions. Solution shown (FEM model, software KRASTA) in figure 15 seems to me most suitable for Serbian market and future container terminals in domestic river ports, and present a general design with some later possible modifications.

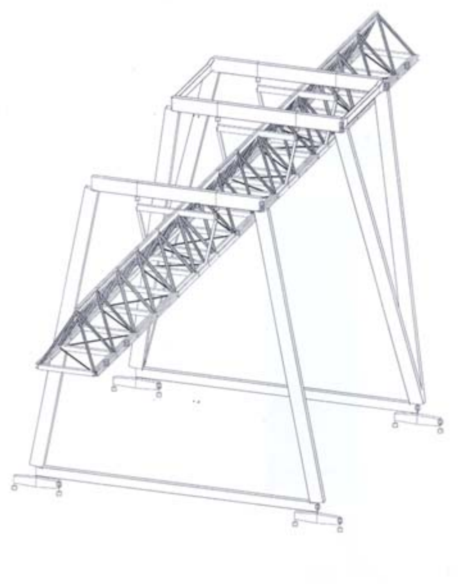

**Figure 15. Quayside container crane with 3D truss girder**

It is suggestible to calculate supporting structure according to criteria of life cycle, i.e. estimated spectra of loadings and number of cycles as defined in EN standards for cranes. Other equipment used for reloading containers at least from trucks should also enable at the same time the connection between yard storage and dock by straddle carriers and reach stackers.


## ACKNOWLEDGMENT

This paper is a part of the research project with specified topic TD 7005 "New methods for defining factors of optimal functioning of river shipping technological subsystems", and research project TR 6344 "Research, development and construction of machines for handling and stocking of containers and bulk materials", both supported by Serbian Ministry of Science and Environmental Protection, as well as EU project INTERREG III B CADSES "Integration in the intermodal goods Transport of non EU states".


## REFERENCES


[1] Chin,-I.L, Hossein, J., Ioannou, A.: Design, simulation and evaluations of automated container terminals, IEEE Transactions on Intelligent Transportation Systems, Vol. 3, No. 1, pp. 12-26,March 2002.

[2] Commission of the European Communities: *Freight logistics in Europe – key to sustainable mobility*, Brussels, June 2006.

[3] Georgijević, M, Kostić, R.: Erhoehung der Lebensdauer von Foerdermaschinen durch Mechatronische Systeme, DVM-Bericht 130, pp 139- 163, 2003.

[4] Georgijević, M., Zrnić N.: Technical parameters and constructions of container cranes for river port terminals, Proc. of the 9th International Conference “Mechanical Engineering”, Slovak University of Technology, pp. 265-274, Bratislava, 2005.

[5] Georgijević, M., Zrnić N., Arsenijević, A., Gašić, V.: Machines for handling containers, are we ready for international competition, Proc. of the 5th International conference “Heavy Machinery”, pp. IA.43 – IA.48, Kraljevo, 2005.

[6] Georgijević, M, Zrnić N, Roknić, S, Bojanić V.: Container terminals of river ports Workshop Transport and Logistics, pp 16.1 – 16.6. Niš, 2006. (in Serbian)

[7] Zrnić, N.: The influence of some container cranes design characteristics on terminal system performances, In: Modeling and Optimization of Logistic Systems (edited by T. Banayai and J. Cselenyi), University of Miskolc, Hungary, pp. 159-171, 2001.

[8] Zrnić, N, Petković, Z., Bošnjak, S.: Basic principles in design of large container cranes (part I): Mechanical design of trolley and environmental impact, Journal of Mechanical Engineering Design, Volume 8, Number 1, pp. 10 – 23, JUDEKO, FTN Novi Sad, 2005.