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# METODOLOGIJA UTVRĐIVANJA POTREBITE MEHANIZACIJE ZA RAD I USLUŽIVANJE KONTEJNERSKOG TERMINALA

*SAŽETAK*

*U radu je obrađena metodologija utvrđivanja mehanizacije za rad i usluživanje kontejnerskog terminala. Izbor vrste i tipova te broja manipulacijskih sredstava provodi se po proračunu koji uzima u obzir vrijeme za obavljanje određene operacije, zatim normiranje vremena ukrcaja ili iskrcaja. U proračun se uzima i kapacitet prekrcajnih sredstava koji se može izračunati kao eksploatacijski ili realni kapacitet. Pregledom veličina i kapaciteta kontejnerskih dizalica i kontejnerskih prijenosnika definirana je metodologija za odabir potrebite mehanizacije.*

## UVOD

Izbor prekrcajne i manipulacijske mehanizacije u terminalu vrlo je složena zadaća, poglavito u srednjim i velikim terminalima. Izbor i kapaciteti prekrcajne i manipulacijske mehanizacije za rad i usluživanje malih kontejnerskih terminala nisu veliki problem, jer se u tim terminalima uglavnom koristi jedno prekrcajno sredstvo. Najčešće se koriste autodizalice, viličari ili kontejnerski manipulatori (bočni ili čelni), i to uglavnom jedno od sredstava ili njihove kombinacije, npr. autodizalice za prekrcaj i viličar za razmještaj i slaganje kontejnera.

U velikim lučkim terminalima, kapaciteta više stotina kontejnera u danu, uz susretanje više prometnih grana (pomorski, željeznički, cestovni, a u nekim lukama i riječni), metodologija utvrđivanja potrebite mehanizacije znatno je složenija. Polazne su pretpostavke za izbor i kapacitet prekrcajne i manipulacijske mehanizacije - statički i dinamički kapacitet terminala, veličina odlagališta kontejnera i broj razina slaganja kontejnera. Pritom se uzimaju u obzir eksploatacijski i tehničko-tehnološki aspekti, koji su složeni od niza čimbenika što bitno utječu na odabir mehanizacije.

Stoga je pri izboru i definiranju kapaciteta mehanizacije potrebito sagledati sve relevantne čimbenike kako bi se izbjegle pogreške koje kasnije mogu imati znatan utjecaj na svekoliki kapacitet terminala.

# METHODOLOGY FOR SELECTION OF REQUIRED UNITS OF MECHANIZED FLEET FOR OPERATION AND HANDLING IN CONTAINER TERMINALS

*SUMMARY*

*The paper deals with the methodoloy for establishing the units of mechanized fleet for operation and handling in container terminals. Selection of the type and number of manipulation equipment is completed based upon the computation (estimate) taking account of the time needed for the completion of individual operation, and setting the time quota for loading and unloading. Also included in the computation is the capacity of reloading equipment from which we are able to work out the utilization-related i.e. actual capacity. By review of dimensions and capacities of container cranes and straddle carriers the methodology for selection of the needed fleet is completed.*

## INTRODUCTION

Selection of reloading and manipulation mechanization to be utilized in a terminal refers to a very complex task, especially in medium and large terminals. Selection and capacities of reloading and manipulation mechanization needed for the operation and handling operations in small container terminals is not a major issue because as a rule only reloading equipment is used at such terminals. The equipment used includes mostly truck-mounted cranes, fork-lift trucks, and container handling units (front and lateral), and then usually a single unit is needed or a particular combination as for instance, a truck-mounted crane for reloading and a fork-lift truck for arrangement and stowing of containers.

At big port terminals designed for handling several hundred containers daily, where we see different transport aspects in action (sea, rail and road transport, and in some ports also river transport), respective methodology for establishing the number and type of required mechanization involves a complex procedure. Points of departure for the selection and capacities of reloading and manipulation equipment refer to fixed terminal facilities and mechanized fleet, size of container lay-down area, and number of levels for arrangement/stowing of containers. In the process acount is taken of engineering and technological

# 1. PROGRAMIRANJE VRSTA I BROJA POTREBNE MANIPULACIJSKE I PRETOVARNE MEHANIZACIJE

Sredstva za manipulacije koja se koriste u kontejnerskim terminalima moguće je razmatrati s više aspekata:
- eksploatacijskog i
- tehničkih aspekata.

Prema eksploatacijskim značajkama, sredstva za manipulaciju dijele se u podskupine:
- po obilježjima tereta
- po mjestu na kojemu se upotrebljavaju
- po načinu kretanja jedinice tereta.[1]

Prema obilježjima tereta, razlikuje se mehanizacija za generalne terete, tekuće i sipke. S motrišta mjesta uporabe, mehanizacija se može koristiti u skladištima, prekrcajnim postajama, terminalima i na mjestu proizvodnje dobara. Kretanje mehanizacije i tereta može pak biti koso, vertikalno i horizontalno.

Teret kojim se manipulira u kontejnerskim terminalima su kontejneri pri kontejnerskom prijevozu te izmjenjivi sanduci, poluprikolice i kamioni pri huckepack ili Ro-Ro prijevozu. Za premještanje kontejnera pri utovaru, istovaru ili odlaganju koristi se pretovarna mehanizacija koja radi s prekidima uz primjenu Lo-Lo, Ro-Ro ili kombinirane tehnologije. To znači da se teret može premještati vertikalnim podizanjem i spuštanjem, horizontalnim kretanjem ili kombinacijom obiju vrsta gibanja.

Izbor vrste, tipova i broja sredstava za manipulacije ovisi o nizu čimbenika. To su:
- tip kontejnerskog terminala (lučki, kontinentalni)
- veličina terminala (mali, srednji ili veliki)
- prometne grane koje se susreću u terminalu
- kapacitet terminala.

Pri pretovarnim manipulacijama u kontejnerskim terminalima koriste se različita sredstva za manipulacije čiji kapacitet, brzina manipulacija, nosivost, proizvodnost i ekonomičnost ovise o nizu čimbenika vezanih uz tehnologiju i organizaciju rada u svakom terminalu. Pretovarnu mehanizaciju u kontejnerskim i Ro-Ro terminalima čine portalne dizalice (prekrcajni tornjevi), kontejnerski mostovi, manipulatori malog i velikog raspona i razne vrste viličara.

U definiranju i programiranju vrsta i broja potrebitih sredstava za manipulacije polazi se od:
- vremena potrebnog za obavljanje određene radnje utovara, istovara i pretovara[2]
- vremena potrebnog za pretovar s obzirom na tip i veličinu kontejnera i tehničke mogućnosti pretovarnog sredstva.

Vrijeme potrebno za realizaciju pretovarne manipulacije "T" utovara-istovara, ovisno o manipulacijskim sposobnostima pretovarnog sredstva, izračunava se prema izrazu:

$$T = t_{pro} + \frac{n}{m} t_{zo} + t_{ui}$$

gdje su:

$t_{pro}$ – vrijeme trajanja pripremnih operacija neposredno prije početka istovara kontejnera

n – broj transportnih sredstava u skupini za istovar

m – broj vozila na kojima se obavlja pretovarna manipulacija uz uporabu više pretovarnih sredstava

$t_{zo}$ – trajanje završnih operacija neposredno nakon istovara vozila

$t_{ui}$ – trajanje operacija utovara ili istovara

Definiranje i normiranje vremena utovara ili istovara kontejnera obavlja se prema izrazu:

aspects, including a series of elements of essential importance and impact upon the selection of equipment.

Consequently, in the process of selection and defining of equipment capacities, it shall be necessary to take into account all relevant factors, in order to avoid errors which can at some later point of time exert significant influence upon the overall capacity of a terminal.

# 1. PROGRAMMING THE TYPES AND NUMBER OF REQUIRED MANIPULATION AND RELOADING EQUIPMENT

Manipulation units used in container terminals can be considered from different aspects including:
- utilization and
- engineering aspect.

According to their utilization-aspected characteristics, manipulation units fall into respective sub-groups based upon
- load characteristics
- utilization location
- load unit movement characteristics[1]

With reference to load characteristics we discriminate among mechanization for general loads, liquid and bulk loads. With reference to respective utilization location, mechanization can be used in warehouses, reloading stations, terminals and on goods manufacturing location. With reference to the aspect of load unit movement, mechanized fleet units and load can move laterally, vertically and horizontally.

The load being manipulated at container terminals are containers in the process of transport, while exchangeable crates, semi-trailers and trucks are used in piggy-back or RO-RO transport. For shifting of containers at the time of loading, unloading or stowing, reloading mechanization is utilized, being employed at intervals, using the LO-LO, RO-RO or combined technologies. This means that the load can be shifted by vertical lifting and putting down, horizontal shifting or combining the two aspects of movement.

Selection of the type, kinds and number of units of manipulation equipment depends on a variety of factors:
- respective type of container terminal (port or land)
- terminal size (small, medium, large)
- terminal capacity.

In the process of reloading manipulation at container terminals different handling equipment is used, whose capacity, speed, carrying capacity, productivity or output, and economy, depend on a series of factors related to the technology and management of operations at each terminal. Reloading mechanization utilized at container and RO-RO terminals includes gantry cranes (reloading towers), container bridges, and manipulation units of small and large range, and different types of fork-lift trucks.

In defining and programming the type and number of required manipulation equipment we consider
- the time required for completion of a given operation of loading, unloading and reloading[2], and
- the time required for reloading as related to the type and size of a container and designed scope of a reloading unit.

The time required for completion of a reloading operation "T", loading-unloading, as dependent upon the manipulation scope of the reloading unit, is computed according to

$$t_{ui} = \frac{p_s \cdot 60}{Q} + t_{po}$$

gdje su:

ps – prosječna težina tereta po kontejneru u tonama

Q – proizvodnost utovarno-istovarnog uređaja u tonama na sat (t/h)

$t_{po}$ – utrošak vremena za izvršenje pomoćnih operacija tijekom utovara-istovara u minutama

Proizvodnost manipulacijskih sredstava Q izračunava se za sredstva koja djeluju s prekidima, kao što su kontejnerske dizalice, manipulatori i viličari, prema izrazu:

$$Q = G \cdot \frac{3600}{T} \quad (kN/h)$$

gdje su:

Q – količina izmanipuliranog tereta u kN na sat

G – težina tereta u jednom zahvatu, koji se premješta u jednom ciklusu u kN

T – trajanje jednog ciklusa u sekundama - vrijeme između dvaju zahvata tereta

$\frac{3600}{T}$ – broj ciklusa u jednom satu

Stvarna proizvodnost ili realni kapacitet pretovarnih sredstava razlikuje se od tehničke norme, jer se ovdje uzima stvarno vrijeme rada manipulacijskog sredstva i iskorištenje fonda vremena u jednoj smjeni ili radnom danu. Radni kapacitet je količina tereta ili kontejnera izražena u tonama, komadima (broj kontejnera) ili kubičnim metrima, pretovarena u jednoj smjeni ili danu, a izračunava se prema općim izrazima:

$$Q\ (kN/dan) = Q\ (1 - \rho) \cdot \tau \cdot \alpha$$
$$Z\ (kom./dan) = Z\ (1 - \rho) \cdot \tau \cdot \alpha$$
$$V\ (m^3/dan) = V\ (1 - \rho) \cdot \tau \cdot \alpha$$

gdje su:

Q, Z, V - tehnička norma proizvodnosti

ρ – gubitak vremena u postotku tijekom nominalnoga radnog vremena

τ – broj nominalnih radnih sati u smjeni i danu

α – koeficijent koji se sastoji od tehničko-tehnoloških i organizacijskih čimbenika koji smanjuju tehničku proizvodnost, a ovisi o pretovarnom sredstvu, vrsti tereta (kontejnera) i uvjetima rada, i manji je od 1 ($\alpha \leq 1$).

Ako se želi izračunati eksploatacijski odnosno realni kapacitet za manipulacijsko sredstvo koje djeluje s prekidima, kao što je mehanizacija u terminalu, tada izraz za izračunavanje glasi:

$$Q_e = \frac{3600}{T} \cdot G \cdot \xi \cdot \tau \cdot \psi \cdot (1 - \rho) \quad (kN/dan)$$

gdje su:

$\frac{3600}{T} = C$ – broj ciklusa zahvatnog elementa - spreader ili vilice na sat, pri čemu je "T" vrijeme trajanja ciklusa izraženo u sekundama

G – nosivost manipulacijskog sredstva u kN, a koeficijent korisne nosivosti predstavlja odnos između nominalne nosivosti $G_n$ i korisne nosivosti $G_k$; pritom na korisnu nosivost utječe težina zahvatnog uređaja (spreader) $G_z$ i time je smanjuje ($\xi \leq 1$) odnosno

$$\xi = \frac{G_n - G_z}{G_n} = \frac{G_k}{G_n} \leq 1$$

ψ – koeficijent zahvata (kod sipkih tereta popunjenost zahvatnog uređaja, a kod kontejnera zahvat od prvog pokušaja); manji je od 1

$$T = t_{pro} + \frac{n}{m} t_{zo} + t_{ui}$$

where

$t_{pro}$ – is the duration of preliminary operations immediately preceding container unloading

n – is the number of units of mechanized fleet on the reloading group

m – is the number of vehicles subject to reloading by employment of several reloading units

$t_{zo}$ – is the duration of final operations immediately following vehicle unloading

$t_{ui}$ – is the duration of loading operations or unloading operations.

Defining and setting a time quota for container loading or unloading is completed per

$$t_{ui} = \frac{p_s \cdot 60}{Q} + t_{po}$$

where

Ps – is the average weight of load per container in tons

Q – is the productivity or output of a loading/unloading unit in tons per hour (t/h)

$t_{po}$ – is the period needed for completion of auxiliary operations in the course of loading/unloading in minutes.

Productivity or output of a manipulation unit Q is computed for units employed at intervals as container cranes, handling units, fork-lift trucks according to

$$Q = G \cdot \frac{3600}{T} \quad (kN/h)$$

where

Q – is the quantity of handled load in kN per hour

G – is the weight of load in a single operation of taking hold of as being shifted during one cycle in kN

T – is the duration of a single cycle in seconds - the period between two manipulations of a load

$\frac{3600}{T}$ – is the number of cycles in an hour.

The actual output or actual capacity of reloading units differs from the technical quota because the actual time of operation of a manipulation unit is taken here and the actual use of working hours in a shift or a workday. Operational capacity is the quantity of load or containers expressed in tons, pieces (number of containers) or cubic meters, reloaded in a shift or a day, and computed by means of

$$Q\ (kN/day) = Q\ (1 - \rho) \cdot \tau \cdot \alpha$$
$$Z\ (piece/day) = Z\ (1 - \rho) \cdot \tau \cdot \alpha$$
$$V\ (m^3/day) = V\ (1 - \rho) \cdot \tau \cdot \alpha$$

where

Q, Z, V - represent technical output quota

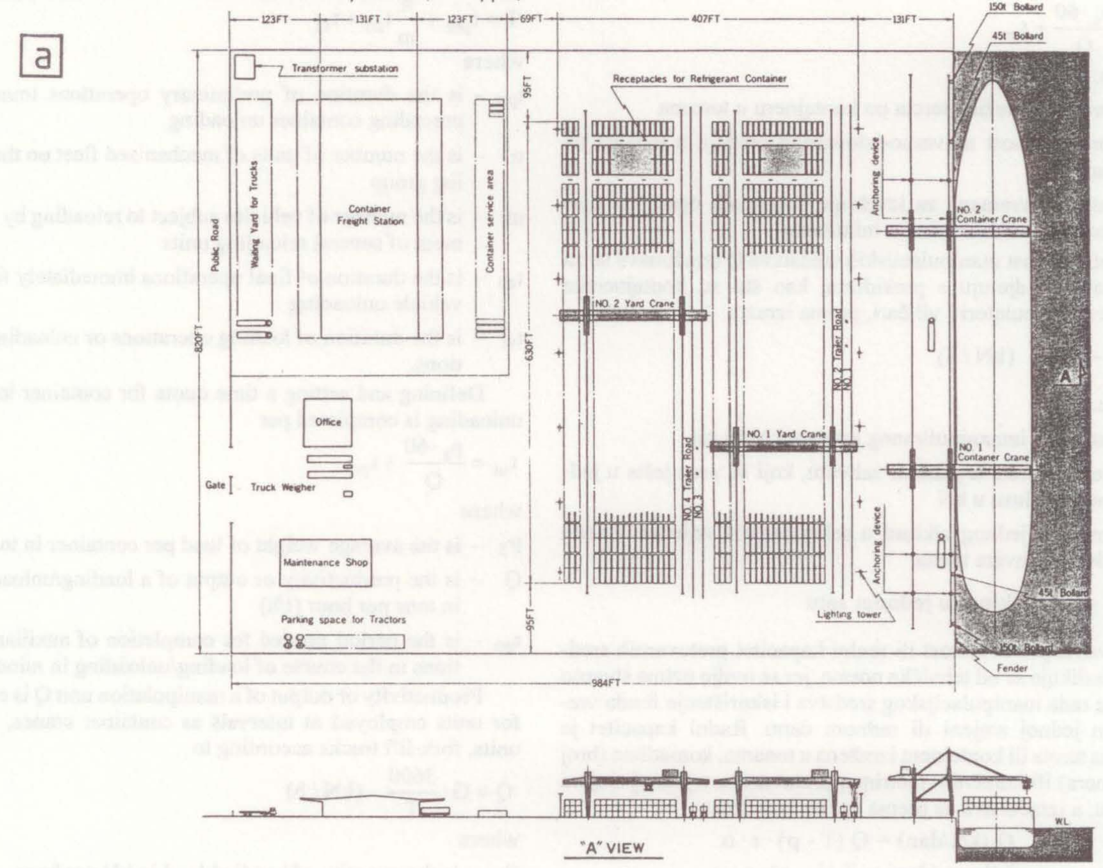
ρ – is loss of time percentage value during nominal working hours

τ – is the number of nominal working hours in a shift or in a day

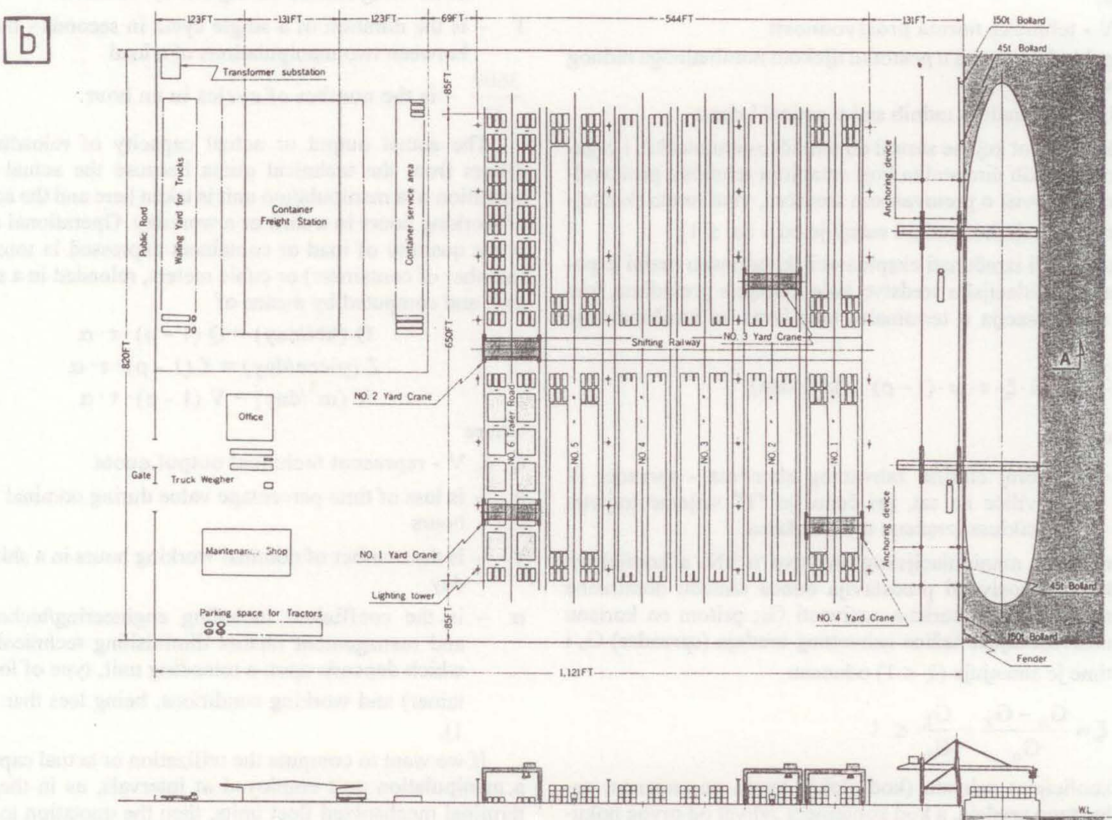
α – is the coefficient including engineering/technological and management factors diminishing technical output, which depends upon a reloading unit, type of load (container) and working conditions, being less than 1 ($\alpha \leq 1$).

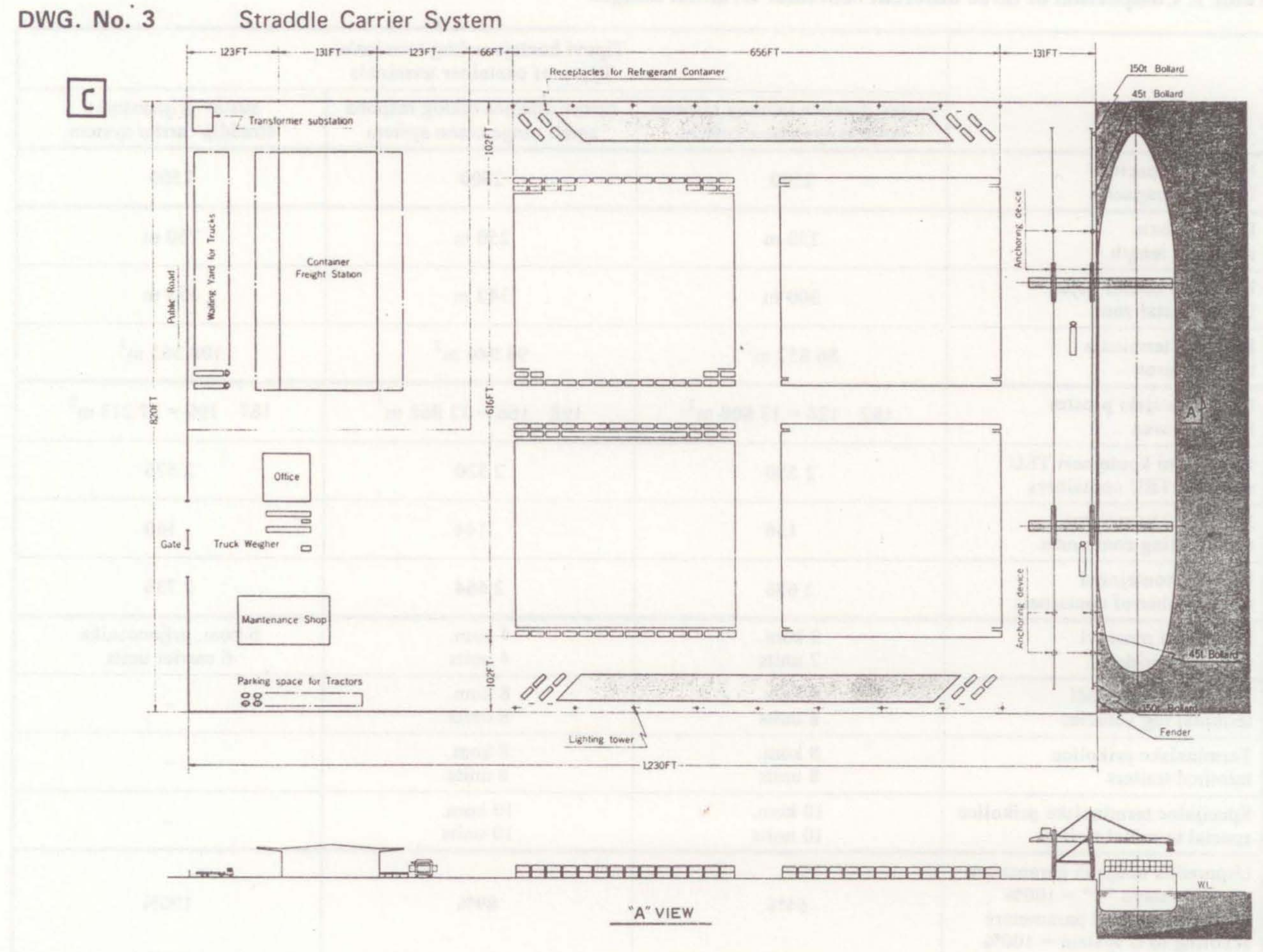
If we want to compute the utilization or actual capacity for a manipulation unit employed at intervals, as in the case of terminal mechanized fleet units, then the quotation to be used is

DWG. No. 1 Yard Crane System (A Type)




DWG. No. 2 Yard Crane System (B Type)






**Slika 1. Različiti sustavi i tipovi lučkih kontejnerskih terminala**
a) sustav dizalica širokog raspona
b) sustav dizalica malog raspona
c) sustav prijenosnika
Izvor: IHI, Tokyo, Japan, 1989, p. 2 i 3.

**Figure 1. Different systems and types of port container terminals**
(a) large range crane system
(b) small range crane system
(c) straddle carrier system
Source: IHI, Tokyo, Japan, 1989, p. 2. and 3.

$\tau$ – koeficijent iskorištenja nominalnog radnog vremena u postotku gdje je $(1 - \rho) \leq 1$

$\rho$ gubitak vremena u postotku gdje je $\rho = 0{,}1 \div 0{,}25$

$\tau (1 - \rho)$ – efektivno radno vrijeme manipulacijskog sredstva u satima

S obzirom na to da je $G_n \cdot \xi \cdot \psi = G$ - stvarno prosječno zahvaćanje kontejnera ili materijala u ciklusu, iz toga proizlazi izraz za eksploatacijsku normu proizvodnosti rada tj. kapacitet manipulacijskog sredstva s isprekidanim djelovanjem:

$$Q_e = \frac{3600}{T} \cdot G \cdot (1 - \rho)\tau \quad (\text{kN / dan})$$

Pri planiranju sredstava za manipulaciju u kontejnerskom terminalu potrebno je voditi računa o brzini pretovara jer transportna sredstva u toj fazi miruju, a to znači da se za vrijeme te operacije nalaze izvan eksploatacije. U gotovo svim granama brzina prijevoza se povećava pa je radi ukupnih učinaka potrebno ubrzati pretovarne manipulacije kako bi se cjelokupni ciklus transporta što brže odvijao i na taj način postigli odgovarajući ekonomski učinci.

$$Q_e = \frac{3600}{T} \cdot G \cdot \xi \cdot \tau \cdot \psi \cdot (1 - \rho) \quad (\text{kN / day})$$

where

$\frac{3600}{T} = C$ – is the number of cycles of a handling unit - a spreader or a fork member per hour, T being the duration of a cycle expressed in seconds

G – the carrying capacity of a manipulation unit in kN, while the coefficient of usefull carrying capacity represents the relation between the installed carying capacity $G_n$ and useful carrying capacity $G_k$, where the useful carying capacity is affected by the weight of the handling member (spreader) $G_z$ and is consequently reduced ($\xi \leq 1$) i.e.

$$\xi = \frac{G_n - G_z}{G_n} = \frac{G_k}{G_n} \leq 1$$

$\psi$ – is the coeficient of hold (with bulk loads the degree of unit being filled up and with containers grip in first attempt), is less than 1

**Tablica 1. Usporedba triju različitih izvedaba kontejnerskog terminala**
**Table 1. Comparison of three different container terminal designs**

| | Tipovi kontejnerskog terminala<br>Types of container terminals | | |
|---|---|---|---|
| | sustav dizalica velikog raspona<br>large range crane system | sustav dizalica malog raspona<br>small range crane system | sustav prijenosnika<br>straddle carrier system |
| Nazivni kapacitet<br>Designed capacity | 2500 | 2500 | 2500 |
| Duljina obale<br>shoreline length | 250 m | 250 m | 250 m |
| Unutarnji obalni pojas<br>inner coastal zone | 300 m | 342 m | 375 m |
| Površina terminala<br>terminal area | 86 852 $m^2$ | 98 944 $m^2$ | 108 565 $m^2$ |
| Manipulacijski prostor<br>handling area | $192 \cdot 124 = 13\,808\ m^2$ | $198 \cdot 166 = 32\,868\ m^2$ | $187 \cdot 199 = 37\,213\ m^2$ |
| Standardni kontejneri TEU<br>standard TEU containers | 2 550 | 2 520 | 2 576 |
| Rashladni kontejneri<br>refrigerating containers | 136 | 144 | 160 |
| Ukupno kontejnera<br>total number of containers | 2 686 | 2 664 | 2 736 |
| Pretovarni mostovi<br>reloading bridges | 2 kom.<br>2 units | 4 kom.<br>4 units | 6 kom. prijenosnika<br>6 carrier units |
| Terminalski tegljači<br>terminal tug vehicles | 8 kom.<br>8 units | 8 kom.<br>8 units | – |
| Terminalske prikolice<br>terminal trailers | 8 kom.<br>8 units | 8 kom.<br>8 units | – |
| Specijalne terminalske prikolice<br>special terminal trailers | 10 kom.<br>10 units | 10 kom.<br>10 units | – |
| Usporedba ukupnih parametara prema sustavu "C" = 100%<br>comparison of all parameters accoring to C system = 100% | 64% | 89% | 100% |

Izvor: IHI, Tokyo, Japan, 1989. p. 4.
Source: IHI, Tokyo, Japan, 1989, p. 4.

## 2. PREGLED VELIČINA I KAPACITETA KONTEJNERSKIH DIZALICA

Pod kontejnerskim dizalicama razumijevaju se sredstva za manipulacije, koja se koriste za prętovar velikih tzv. transkontejnera. Za manipulacije s malim kontejnerima upotrebljavaju se različite vrste viličara. Dimenzije i raspon dizalica ovise o tomu radi li se o lučkom ili kontinentalnom terminalu, o širini brodova koje treba uslužiti, o broju željezničkih kolosijeka, cestovnih prometnica i odlagališnih trakova. Nosivost dizalica vezana je uz veličinu i težinu kontejnera koje uslužuje. S obzirom na intenzivan rast kontejnerskog prometa i broj kontejnera u opticaju, kapacitet dizalica stalno se povećava.[3]

U lučkim kontejnerskim terminalima koriste se portalne i mosne dizalice i kombinacija tih dizalica. Osim tih dizalica, koje mogu biti stabilne i pokretne po uzdužnoj osi, koriste se prijenosnici malog i velikog raspona. Među najpoznatije proizvođače kontejnerskih dizalica pripadaju Paceco, Krupp, Liebherr, Fruehaf, Mijack, Ferranti, Mitsubishi, Davy Morris, Valmet, Takraf, Sea Containers, Hyundai i drugi. Ti proizvođači grade velike portalne i mosne dizalice (Yard gantry cranes), prijenosnike velikog raspona (mobil gantry cranes), prijenosnike malog raspona (straddle carriers). U velikim terminalima za manipulacije koriste se mješoviti sustavi dizalica, prijenosnika i viličara. Pri projektiranju i izgradnji terminala moraju se

$\tau$ – is the coefficient of making use of nominal working hours in precentage value where $(1 - \rho) \leq 1$

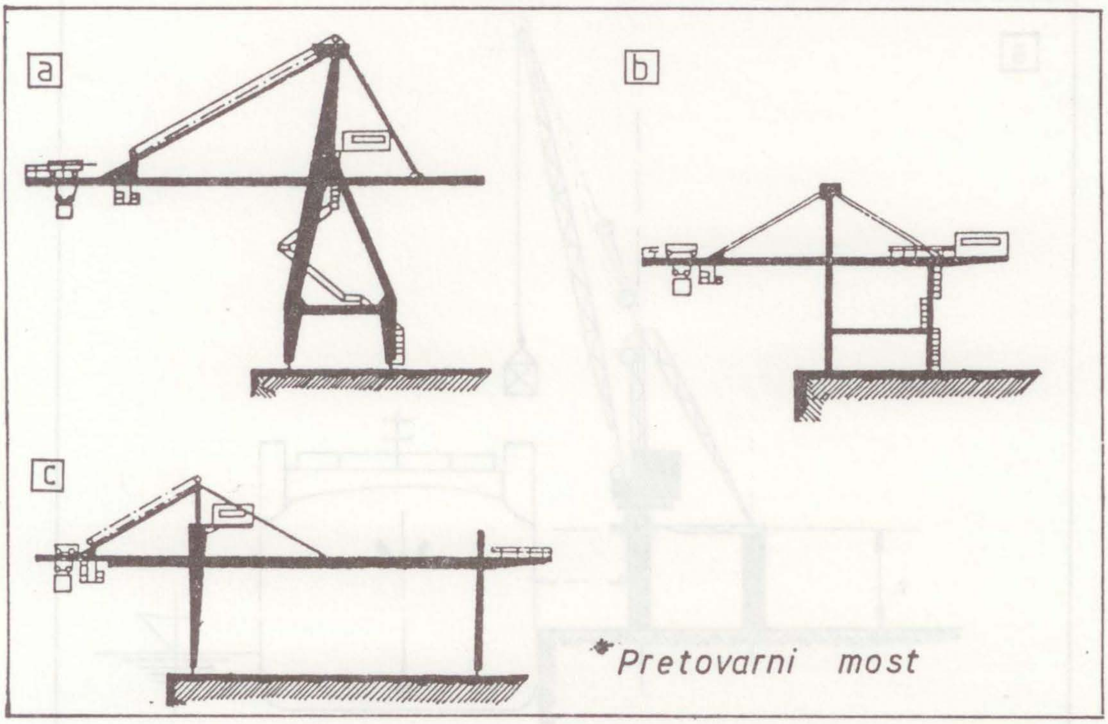
$\rho$ – is the percentage value of loss of time where $\rho = 0.1 \div 0.25$

$\tau(1 - \rho)$ – effective working hours of a manipulation unit in horus.

Considering that $G_n \cdot \xi;\ \psi = G$ - actual average hold of a container or material in a cycle, this gives the expression for the utilization-related productivity (output) quota i.e. the capacity of manipulation unit engaged at intervals

$$Q_e = \frac{3600}{T} \cdot G \cdot (1 - \rho)\tau \quad (kN/day)$$

In the process of planning the equipment for manipulation at container terminals it is necessary to take acount of the speed of reloading in view of the fact that transport means are stationary in this phase, not being utilized until this operation is finished. In almost all segments, transport speeds are increased so that it is necessary for reasons of aggregate effects to speed-up the reloading manipulations in order to have the entire cycle of transport running more quickly and to reach corresponding economic effects in this manner.




**Slika 2. Prikaz različitih izvedaba portalnih dizalica**
**Figure 2. View of different gantry crane designs/configurations**

iznalaziti cjelovita rješenja i kombinacija raznih vrsta sredstava za manipulacije s kontejnerima. Na primjeru tvrtke IHI (Shikawajima - Harima Heavy Industries Co., Ltd) iz Japana, u lučkim terminalima moguća su tri rješenja za manipulacije: sustav pokretnih dizalica i pretovarnih mostova velikog raspona (a), sustav portalnih dizalica i pokretnih dizalica malog raspona (b) i sustav prijenosnika malog i velikog raspona (c), pokazani na slikama 1,a, b i c.

Usporedbom svih triju rješenja, pri čemu se polazi od toga da se u danu skladišti 2500 kontejnera od 20', moguće je uočiti prednosti i nedostatke svakog od njih.

Kod dizalica druge i treće generacije povećana je nosivost do 450 kN, brzina dizanja tereta 8-10 m u minuti, brzina kretanja teleskopskog spreadera 40 m u minuti i brzina kretanja cijele dizalice 80 m u minuti. Visina dizanja tereta je 10,5 - 15,5 m, a to omogućuje odlaganje kontejnera do razine od 4-6 kontejnera.

Obalne portalne dizalice pokazane na slici 2. mogu imati različit dohvat tereta, 25-35 m.

Dohvat dizalica je različit prema izvedbi u pravcu broda i prema kopnu. Povećanje kapaciteta u ukrcaju i iskrcaju postiže se kod pretovarnih tornjeva tipa "škotska samarica" koja ima veliko zakretanje krana, a pokretna je i po uzdužnoj osi.

U kopnenim kontejnerskim terminalima pretovarni kontejnerski mostovi mogu biti različite izvedbe glede raspona, brzine dizanja i kretanja visine dizanja što ovisi o namjeni terminala, broju željezničkih kolosijeka, cestovnih prometnica, odlagališnih trakova i njihovoj duljini.

## 3. PREGLED VELIČINE I KAPACITETA KONTEJNERSKIH PRIJENOSNIKA

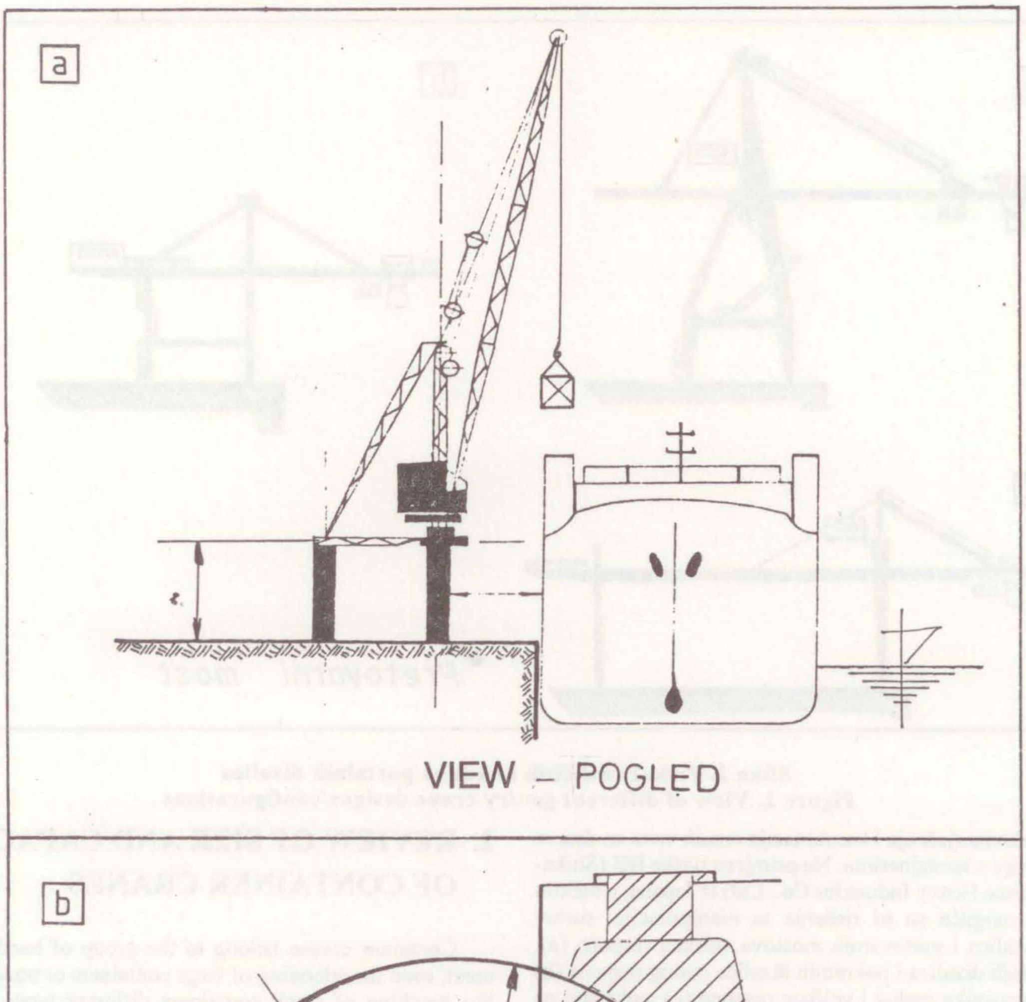
Za pretovar kontejnera s kopnenih transportnih sredstava i njihovo odlaganje u lučkim i kontinentalnim terminalima kori-

## 2. REVIEW OF SIZE AND CAPACITIES OF CONTAINER CRANES

Container cranes belong to the group of handling equipment, used for relaoding of large containers or transcontainers. For handling of small containers different types of fork-lift trucks are used. Dimensions and span of these cranes depend upon whether they are used in a port or a land terminal, width of vessels to be handled, number of rail tracks, road traffic routes and stowing conveyers. Carrying capacity of cranes is determined by the size and weight of containers to be handled. Considering vigorous growth of container transport and number of containers being used, the capacity of cranes is being steadily extended.[3]

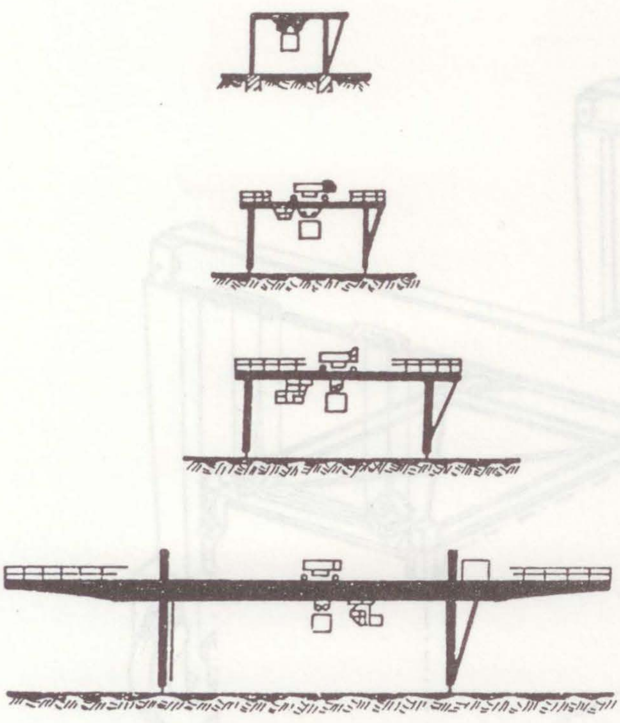
In port container terminals gantry cranes, bridge cranes and a combination of the two types are used. In addition to these cranes, which may be fixed and mobile along the longitudinal axis, conveyers of small and large span are utilized. Major manufacturers of container cranes are Paceco, Krupp, Liebherr, Fruehaf, Mijack, Ferranti, Mitsubishi, Davy Morris, Valmet, Takraf, Sea Container, Hyundai, etc.

These manufacturers produce big ganty and bridge cranes (Yard gantry cranes), conveyers of large range (mobile gantry cranes), and conveyers of small range (straddle carriers). In large terminals mixed configuration systems of cranes, conveyers and fork-lift trucks are utilized for handling. In the process of designing and construction of terminals comprehensive practical propositions must be looked for as well as combinations of different types of units for container manipulation operations. On the pattern of the IHI company (Shikawajima - Harima Heavy Industries Co. Ltd.) of Japan three practical propositions for handling procedures are possible in port terminals: the system of mobile cranes and reloading bridges of large range (a), the system of small range gantry cranes and mobile cranes (b) and the system of conveyers of small and large range (c), chown in Figures 1 a, b, and c.




**Slika 3. Škotska samarica tvrtke Liebherr postavljena u kontejnerskom terminalu Luke Rijeka**

**Figure 3. Scotch derick of Liebherr manufactures installed at Port Rijeka container terminal**



**Slika 4. Prikaz različitih izvedaba kontejnerskih mostova**
**Figure 4. View different container bridge designs/configurations**

ste se prijenosnici širokog raspona, dok se prijenosnici malog raspona koriste za pretovar i razmještanje kontejnera na odlagalištima. Najpoznatiji proizvođači prijenosnika u svijetu su tvrtke: Valmet, Belotti, Mijack, Sea Containers i drugi. Nosivost jednih i drugih prijenosnika je 300-450 kN i predviđeni su za manipulacije s kontejnerima od 20 do 40 stopa.

Ova vrsta prijenosnika naziva se transtainer, a njegove su značajke:

- nosivost 450 kN
- brzina dizanja - s teretom od 18 t = 9,7 cm/s
  - s teretom od 45 t = 4,5 cm/s
- vlastita težina 325 kN
- pogon: dizelski motor 177 kW.

Prijenosnik malog raspona tvrtke Valmet ima ove značajke: može podizati teret do 400 kN, kontejnere od 20-40 stopa, brzina dizanja tereta od 400 kN je 9 m/min, prazni hod 10 m/min, pokreće ga dizelski motor od 220-300 kW, vlastita težina 122 kN.

Pri zahvaćanju kontejnera koriste se različite vrste spreadera, tako da se za portalne dizalice, kontejnerske mostove i prijenosnike ugrađuju teleskopski spreaderi. Teleskopski spreaderi zahvaćaju kontejner s gornje strane i vertikalnim podizanjem i spuštanjem obavlja se pretovar. Kod pojedinih dizalica i prijenosnika postoji mogućnost zakretanja spreadera za 90$^{o}$ što povećava manipulacijsku sposobnost dizalica i prijenosnika.

Izbor spreadera ovisi o vrsti kontejnera koji se najčešće susreću u kontejnerskom terminalu. Kontejneri od 10 stopa pretovaruju se viličarima dok se za kontejnere iznad 20 stopa koristi mehanizacija sa spreaderima.

Izbor potrebnih manipulacijskih sredstava obavlja se na temelju stvarnog ili pretpostavljenog obujma pretovara, tehničkih značajki pojedinoga manipulacijskog sredstva i proračuna potrebnih sredstava prema danim parametrima. Za navedene manipulacije u manjim se terminalima mogu koristiti autodiza-

By comparsion of these three practical propositions, taking account of the fact that 2,500 20'-containers are placed in to storage on a daily basis, it is possible to establish the advantages and disadvantages of each of them.

With cranes of the second and third generation, respective carrying capacity has been increased up to 450 kN, speed of lifting the load to 8-10 meters per minute, speed of movement of telescopic spreader to 40 meters per minute, and speed of movement of the entire crane to 80 meters per minute. The height of lifting the load varies from 10.5 to 15.5 meters, making possible stowage of containers up to the height of 4-6 containers.

Sea ganty cranes shown in Figure 2 can have different range of hold of the load varying from 25 to 35 meters.

Crane hold span is different as a result of design/configuration in being turned towards the vessel or land. Increase of capacities at loading and unloading is achieved in the reloading towers of Scotch straddler type, of a huge crane radius, also being mobile along the longitudinal axis.

In land container terminals, designs of reloading container bridges can differ in relation to span/range, speed of lifting and movement, and height of lifting, as dependent upon the purpose of a terminal, number of rail tracks, road access routes, laydown lanes and their length.

## 3. REVIEW OF DIMENSIONS AND CAPACITIES OF CONTAINER STRADDLE CARRIERS

For reloading of containers from surface transport vehicles and their stowing in port and land terminals, large span/range straddle carriers are used, while small span/range carriers are used for reloading and arrangement of containers in the laydown area. Most well-known manufacturers of straddle carriers in the world are companies Valmet, Belotti, Mijack Sea Containers and other. Carrying capacities of the two mentioned types of carriers range from 300 to 450 kN and they are designed for manipulation of containers of 20 to 40 feet.

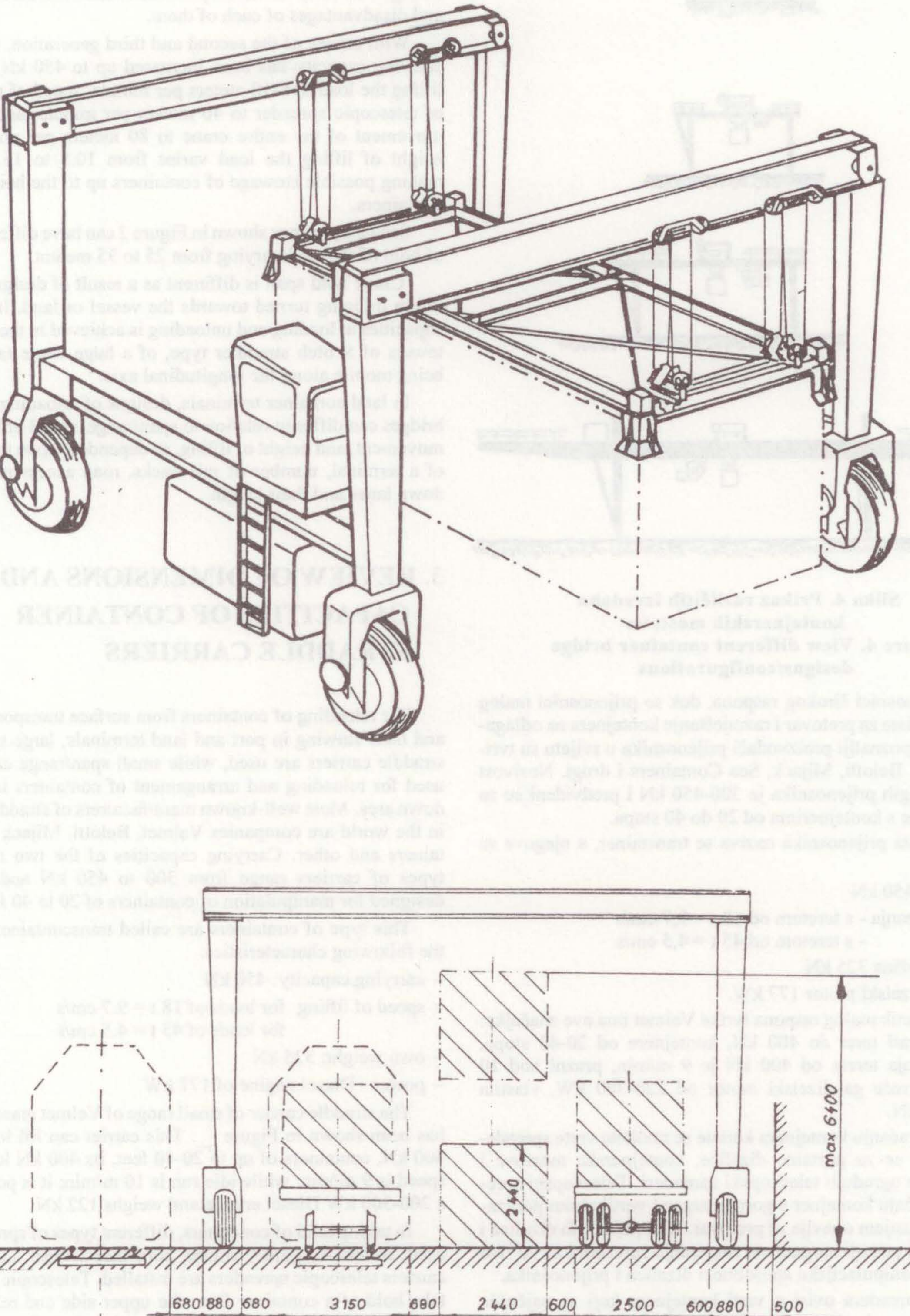
This type of containers are called transcontainers, having the following characteristics:

- carrying capacity: 450 kN
- speed of lifting for loads of 18 t = 9.7 cm/s
  for loads of 45 t = 4.5 cm/s
- own weight: 325 kN
- power - Diesel engine of 177 kW

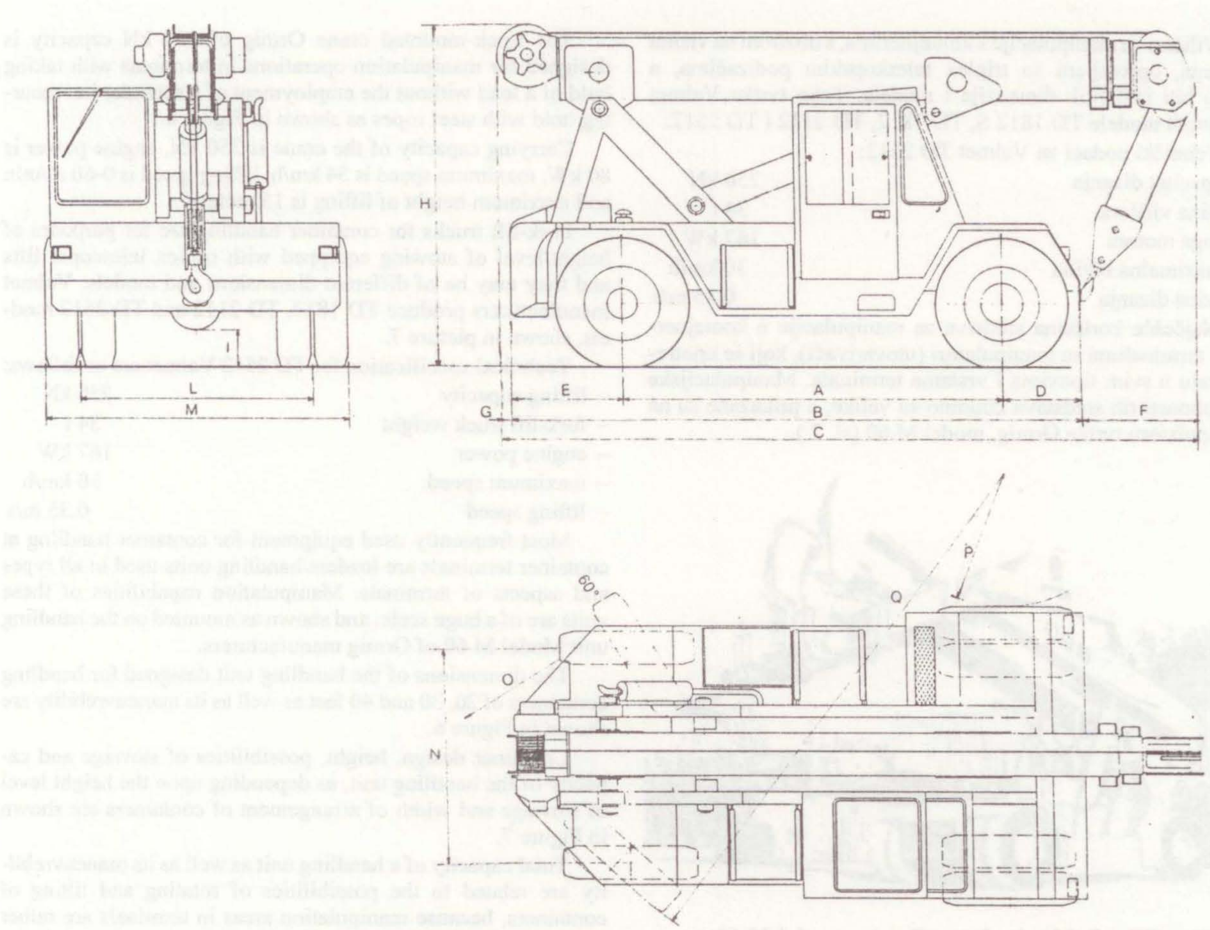
The straddle carrier of small range of Velmet manufacturers has been shown in Figure __. This carrier can lift loads up to 400 kN, containers of up to 20-40 feet, its 400 kN load lifting speed is 9 m/min, while idle run is 10 m/min; it is powered by a 200-300 kW Diesel engine and weighs 122 kN.

In taking hold of containers, different types of spreaders are used, so that for gantry cranes, container bridges and straddle carriers telescopic spreaders are installed. Telescopic spreaders take hold of a container from the upper side and reloading is completed by vertical lifting and lowering. In individual cranes and carriers, spreaders enable the function of being rotated by 90$^{o}$ thus increasing the manipulation capacity of cranes and carriers.

Selection of spreaders depends upon the type of container most frequently seen at a container terminal. Containers of up to 10 feet are reloaded by means of fork-lift trucks while the containers of over 20 feet use fleet units with spreaders.




**Slika 5. Portalni prijenosnik velikog raspona tvrtke Mannesman - Drotl**
**Figure 5. Mobile gantry crane of huge span/range, of Mannesman - Drotl manufacturers**



**Slika 6. Autodizalica Ormig 250 kN**

Kazalo:

| | mm |
|---|---|
| A - razmak između osovina | 3000 |
| B - vanjske dimenzije | 4510 |
| C - vanjske dimenzije uključujući dizalicu | 5520 |
| D - razmak između prednje osovine i ruba vozila | 630 |
| E - razmak između zadnje osovine i ruba vozila | 880 |
| F - razmak između prednjeg ruba i čela dizalice | 930 |
| G - razmak između zadnjeg ruba i zadnjeg dijela dizalice | 80 |
| H - visina od podloge do gornjeg ruba dizalice | 2700 |
| I - minimalna visina od podloge (clearance) | 300 |
| L - razmak između unutarnjih kotača | 1840 |
| M - vanjska širina dizalice | 2400 |
| N - širina voznog traga | 1740 |
| O - širina radijusa traga kružnog okretanja | 4750 |
| P - prednji zakretni radijus | 1400 |
| Q - kosi zakretni radijus | 4700 |

lice, kranomobili i viličari, a u srednjim i velikim, osim tih sredstava, koriste se različite vrste kontejnerskih utovarivača. Svaki od navedenih proizvođača ima u svom proizvodnom programu više vrsta i tipova pretovarnih sredstava različitih tehničko-tehnoloških značajki.

Autodizalica Ormig, kapaciteta 250 kN, namijenjena za manipulacije u terminalu sa zahvaćanjem bez spreadera odnosno kvačenje s čeličnom užadi, pokazana je na slici 6.

Nosivost dizalice je 250 kN, snaga motora 80 kW, maksimalna brzina 34 km/h, brzina dizanja 0-60 m/min, maksimalna visina dizanja 15 metara.

**Figure 6. Truck-mounted crane Ormig of 250 kN**

Key:

| | mm |
|---|---|
| A - axle span | 3000 |
| B - external dimensions | 4510 |
| C - external dimensions including the crane | 5520 |
| D - span between the front axle and the side of the vehicle | 630 |
| E - span between the rear axle and the side of the vehicle | 880 |
| F - span between the front side and the face of the crane | 930 |
| G - span between the rear side and rear section of the crane | 80 |
| H - height of the base to the upper side of the crane | 2700 |
| I - minimum height from the base (clearance) | 300 |
| L - span between inner wheels | 1840 |
| M - outer width of the crane | 2400 |
| N - width of the vehicle movement | 1740 |
| O - width of circular movement radius | 4750 |
| P - front circular movement radius | 1400 |
| Q - transversal circular movement radius | 4700 |

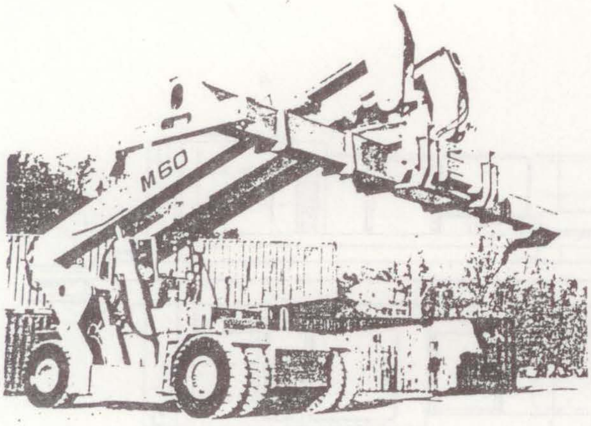
The selection of required manipulation equipment is completed based upon the actual or anticipated scope of relaoding, engineering characteristics of individual manipulation unit and estimate of required units based upon these parameters. For the above mentioned handling operations truck-mounted cranes, cranomobiles and fork-lift trucks can be used in smaller terminals, while in medium and large terminals in addition to these units different types of container loaders are used. Each of the above mentioned manufacturers has on his production program several types and designs of reloading equipment of different engineering/technological characteristics.

Viličari za manipulacije s kontejnerima, s obzirom na visinu slaganja, opremljeni su triplex teleskopskim podizačima, a mogu biti različitih dimenzija i modela. Tako tvrtka Valmet proizvodi modele TD 1812 S, TD 1812, TD 2112 i TD 2512.

Tehnički podaci za Valmet TD 2512:

| | |
|---|---|
| – kapacitet dizanja | 250 kN |
| – težina viličara | 34 t |
| – snaga motora | 167 kW |
| – maksimalna brzina | 30 km/h |
| – brzina dizanja | 0.35 m/s |

Najčešće korištena sredstva za manipulacije u kontejnerskim terminalima su manipulatori (utovarivači), koji se upotrebljavaju u svim tipovima i vrstama terminala. Manipulacijske sposobnosti tih sredstava iznimno su velike, a prikazane su na manipulatoru tvrtke Ormig, model M 60 (sl. 7.).




**Slika 7. Manipulator Ormig, model M 60**
**Figure 7. Model M 60 Ormig handling unit**

Ukupni kapacitet manipulatora kao i njegove manevarske sposobnosti vezane su uz mogućnosti zakretanja i naginjanja kontejnera, jer su u terminalima manipulacijske površine ograničene.

# 4. ZAKLJUČAK

Metodologija utvrđivanja potrebite mehanizacije u kontejnerskom terminalu složen je sustav što zahtijeva tehničko-tehnološki pristup koji vodi računa o eksploatacijskim značajkama manipulacijskih sredstava i kapacitetu terminala. Za velike i srednje terminale najbolja je kombinacija različite mehanizacije kao što su portalne dizalice i prekrcajni mostovi za prekrcaj s jednog sredstva na drugo, a za razvoženje i slaganje kontejnera na odlagalištu dobro je koristiti kontejnerske prijenosnike s promjenjivim spreaderom. U manjim terminalima mogu se koristiti autodizalice i viličari, a pogodno je i korištenje kontejnerskog manipulatora za sve operacije od prekrcajnih, ukrcajnih i iskrcajnih manipulacija do slaganja kontejnera na više razina što je limitirajući čimbenik za viličare. Prikazani modeli za odabir mehanizacije polaze od usporedne analize kapaciteta prekrcajnog sredstva i statičkoga i dinamičkoga kapaciteta terminala. Pritom se polazi od normiranja vremena potrebitog za izvođenje manipulacije ukrcaja ili iskrcaja kontejnera, kako bi se došlo do proizvodnosti ili realnoga kapaciteta prekrcajnog sredstva.

The truck-mounted crane Ormig of 250 kN capacity is designed for manipulation operations in terminals with taking hold of a load without the employment of a spreader i.e. securing hold with steel ropes as shown in Figure 6.

Carrying capacity of the crane is 250 kN, engine power is 80 kW, maximum speed is 34 km/h, lifting speed is 0-60 m/min and maximum height of lifting is 15 meters.

Fork-lift trucks for container handling are for purposes of height/level of stowing equipped with triplex telescopic lifts and they may be of different dimensions and models. Valmet manufacturers produce TD 1812, TD 2112 and TD 2512 models, shown in picture 7.

Technical specification for TD 2512 Valmet are as follows:

| | |
|---|---|
| – lifting capacity | 250 kN |
| – fork-lift truck weight | 34 t |
| – engine power | 167 kW |
| – maximum speed | 30 km/h |
| – lifting speed | 0.35 m/s |

Most frequently used equipment for container handling at container terminals are loaders/handling units used in all types and aspects of terminals. Manipulation capabilities of these units are of a huge scale, and shown as mounted on the handling unit Model M 60 of Ormig manufacturers.

The dimensions of the handling unit designed for handling containers of 20, 30 and 40 feet as well as its maneuvrebility are shown in Figure 6.

Container design, height, possibilities of stowage and capacity of the handling unit, as depending upon the height level of stowage and width of arrangement of containers are shown in Figure 7.

Total capacity of a handling unit as well as its maneuvrebility are related to the possibilities of rotating and tilting of containers, because manipulation areas in terminals are rather restricted. Maneuvering potentials of a handling unit M 60 are shown in Figure 7.

# 4. CONCLUSION

The methodology for establishing the required mechanized fleet to be used in container terminals makes a complex system of procedures, taking account of the utilization-related properties of handling units and terminal capacities. For large and medium terminals the best combination is seen in different units of mechanized fleet as gantry cranes, and reloading bridges, for reloading from one unit on to another, while for transportation and arrangement of containers in lay-down areas straddle carriers with an interchangeable spreader are used. At smaller terminals, truck-mounted cranes and fork-lift trucks can be used, and it would be good to use a container handling unit for all operations ranging from reloading, loading, unloading up to arrangement of containers in several levels, being a limiting factor in case of fork-lift trucks.

The presented models for the selection of mechanized fleet units come as a result of comparative analysis of the capacities of a reloading unit and terminal fixed and mechanized fleet capacities. In the process we take as points of departure establishing the time quota needed for the completion of the manipulation operation of loading, and unloading of containers, in order to reach i.e. determine the output or actual capacity of a reloading unit.


Promet, vol. 7, 1995, No. 1-2, 29-41

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