# DETERMINATION THE OPTIMAL NUMBER OF DEVICES USED FOR MOVEMENT WITH HANDLING UNITS

# STANOVENIE OPTIMÁLNEHO POČTU ZARIADENÍ VYUŽÍVANÝCH NA PREMIESTŇOVANIE MANIPULAČNÝCH JEDNOTIEK

Ondrej Stopka, Marián Šulgan[1]

*Summary:The paper deals with setting the optimal number of devices that are widely used in connection with the handling of intermodal cargo units and also indicating the number of handling devices used for necessity of loading respectively. unloading pallet units of various vehicles and transport units.*

*Key words:handling devices, intermodal cargo units, handling units, mechanization devices*

*Anotácia:Príspevok sa zaoberá stanovením optimálneho počtu zariadení, ktoré sú vo veľkej miere využívané v súvislosti s manipuláciou s intermodálnymi nákladnými jednotkami a tiež určením počtu manipulačných zariadení, ktoré sa používajú pre potrebu nakládky resp. vykládky paletových jednotiek z rôznych dopravných prostriedkov a prepravných jednotiek.*

*Kľúčové slová:manipulačné zariadenia, intermodálne nákladné jednotky, manipulačné jednotky, mechanizačné zariadenia*

## 1. INTRODUCTION

Handling with materials generally means the sum of operations associated with the movement, loading, guiding, positioning, weighing, packaging, dispensing and storage of goods and materials in the sphere of production and circulation [1].

The term handling unit means the arrangement for bulk material or general cargo, which may be handled as one piece and they are created with the help of transport and fixation equipment [1].

For smooth handling with these units it is necessary to ensure the optimal number of devices that are adjustable mainly for their particular movement. This paper deals with determining the optimal number of handling devices for movement of handling units.

[1] Ing. Ondrej Stopka, PhD., Univerzity of Zilina, Faculty of Operation and Economics of transport and Communications, Department of road and Urban Transport,Univerzitná 8215/ 1,01026 Žilina, Slovak republic, Tel.: +4215133523, E-mail: ondrej.stopka@fpedas.uniza.sk
Prof. Ing. Marián Šulgan, PhD., Univerzity of Zilina, Faculty of Operation and Economics of transport and Communications, Department of road and Urban Transport,Univerzitná 8215/ 1,01026 Žilina,Slovak republic, Tel.: +4215133506, E-mail: marian.sulgan@fpedas.uniza.sk

## 2. CALCULATION OF THE NECESSITY OF HANDLING DEVICES USED FOR HANDLING WITH ICU IN INTERMODAL TERMINALS

The calculation relates to determine the operational necessity of same type handling devices for handling with intermodal cargo units (next ICU). The calculations will consider with stacking trucks Kalmar.


Source: [2]

Fig. 1 - Illustration of the truck Kalmar

Subsequent relationship determines the theoretical necessity of trucks Kalmar [3]:

$$Z_c = \frac{(N_{VK}^P + N_{VK}^N) * k_d + k_{vo} * t_{lo}}{(T - T_p) * \alpha_{pv}} * \left(1 + \frac{r}{100}\right) \quad (1)$$

$$Z_c = \frac{N_{LO} + k_{vo} * t_{lo}}{(T - T_p) * \alpha_{pv}} * \left(1 + \frac{r}{100}\right) \quad (2)$$

$$N_{LO} = (N_{VK}^P + N_{VK}^O) * k_d \quad (3)$$

and:

$Z_c$ Total number of one type handling devices,

$N_{LO}$ Average number of incoming and outgoing ICU per day, which is determined by the sum of loadings, unloadings and transhipments of incoming and outgoing ICU,

$N_{VK}^P + N_{VK}^O$ Average number of incoming and outgoing ICU,

$k_d$ Coefficient of depositing that expresses the share of transshipments through storage area, the direct transhipment has a value of 1 and the loading or unloading has a value of 2,

$k_{vo}$ Coefficient of side operations of handling device which are not directly related to the transhipment of ICU (eg. movement of ICU on storage areas, relocation of damaged ICU, etc.).

$t_{lo}$ Average duration of one loading operation ICU (loading, unloading, transhipment), is dependent on the selected mechanization device,

$T$ Daily working time,

$T_p$ Legitimate and necessary technology breaks,

$\alpha_{pv}$ Coefficient of operational using of handling device. It characterizes whether the device actually works all the time during the shift,

$r$ Reserve for the planned scheduled maintenance and planned repairs of handling device, which are determined by producer to ensure of long existence of devices.

**The model of calculation will be based on the following data:**

Value $N_{LO}$ is greatly influenced by the deposition coefficient, because it essentially multiplies the number actually incoming and outgoing ICU. Therefore it is necessary to appropriately set $k_d$, which is different for each category of ICU. For the purposes of calculating the appropriate value will be 1,4 (actual values are between 1,4 and 1,6). In determining $t_{lo}$ some factors are operated, which are taken into account. These are speed of handling device in an empty / loaded condition, the distance that must be overcome, the method of handling and stacking. For handling device it is chosen the value 7 minutes.

Coefficient of secondary operations $k_{vo}$ = 1,1. Daily working time is on average T = 12 hours (720 minutes) and value $T_p$ we determine on 60 minutes ($T$ - $T_p$ = 660 minutes). Coefficient of operational use $\alpha_{pv}$ = 0,8 and provision for planned repairs and maintenance is 15 %.

In the calculations it will be considered with an average daily number of incoming and outgoing ICU 250 pieces.

The total number of manipulated ICU per day:

$$N_{LO} = 250 * 1{,}4 = 350 \text{ ICU} \quad (4)$$

Calculation of appropriate handling devices:

$$Z_c = \frac{350 * 1{,}1 * 7}{660 * 0{,}8} * \left(1 + \frac{15}{100}\right) = 5{,}87 = 6 \quad (5)$$

The calculation shows that by the expected performance of the intermodal terminal it will be sufficient six handling devices for handling with ICU in the inner circle of terminal.

## 3. CALCULATION OF THE NECESSITY OF HANDLING DEVICES USED FOR LOADING PALLET UNITS INTO ICU

In terms of rationalization of loading pallet units into ICU it is appropriate to focus on the forklift truck (the FLT), therefore that these trucks are used at the most for loading or unloading. In calculating of the total required number of FLT we will consider the following equations:

Hour traffic performance of mechanized devices $Q_h$ is given by a basic equation:

$$Q_h = \frac{3600}{t_{cp}} \cdot M_d \qquad (6)$$

$M_d$ - Number of pallet units of a single dose,

$t_{cp}$ - Average duration of the operational cycle of mechanized device (s),

For operational cycle applies:

$$t_{cp} = t_1 + t_2 + t_3 + ..... + tn = \Sigma\, t_i \qquad (7)$$

$t_i$ - Time periods of partial operations of operational cycle,

n - Number of partial operations of operational cycle.

Duration of the complete closure operational cycle is usually composed of the following time periods (in seconds):

$t_1$ - Time necessary to set up a working tool into the position required for the loading of cargo,

$t_2$ - Time necessary for the loading of cargo,

$t_3$ - Time necessary to set up a working tool into the position required for transfer (usually stroke),

$t_4$ - Time necessary to overcome the transport distance in the loaded state,

$t_5$ - Time necessary to set up a working tool into the position required for the unloading of cargo,

$t_6$ - Time necessary for the unloading of cargo,

$t_7$ - Time necessary to set up a working tool into the position required for transfer,

$t_8$ - Time necessary to overcome the return transport distance (driving time in the unloaded state).

On the basis of observed or calculated the total average time of operational cycle of mechanized device ($t_{cp}$) and required time interval between doses, i.e. interval of delivery cycle ($t_{cd}$), respectively required hour traffic performance ($Q_{vh}$), may be determined the operational necessity for mechanized devices of a certain kind:

$$Z_p = \frac{t_{cp}}{t_{cd}} = \frac{n_{cd}}{n_{cp}} = \frac{Q_{vh} \cdot t_{cp}}{3600 \cdot M_d} \quad (8)$$

$n_{cd}$ - Required number of delivery (required) cycles per hour, whichever is:

$$n_{cd} = \frac{Q_{vh}}{M_d} \quad (9)$$

$n_{cp}$ - Number of cycles, which can reach one mechanized device per hour, whichever is:

$$n_{cp} = \frac{3600}{t_{cp}} \quad (10)$$

Required hour traffic performance (capacity) of mechanized devices may be determined for example from the required annual performance ($Q_{vr}$), respectively from the required day performance ($Q_{vd}$):

$$Q_{vd} = \frac{Q_{vr}}{ppd} \quad (11)$$

$$Q_{vh} = \frac{Q_{vd}}{T_{ps}} \quad (12)$$

$T_{cp}$ - Time fund of the working shift, i.e. working time of the shift reduced by necessary technological and working breaks, except of maintenance and repairs (h),

Ppd - number of working days per year,

Total necessary number of certain types of mechanization equipment $Z_c$ is then set so that the calculated operational necessity of mechanized devices will increase even about capacity margin of scheduled and unscheduled repairs and regular maintenance of mechanized devices [3].

$$Z_c = Z_p \cdot \left(1 + \frac{r}{100}\right) = \frac{Q_{vh} \cdot t_{cp}}{3600 \cdot M_d} \cdot \left(1 + \frac{r}{100}\right) \quad (13)$$

$Z_c$ - Total required number of mechanized devices of certain kind,

r - Fixed capacity margin for both planned and unplanned repairs and maintenance of mechanized devices (%).

**The model of calculation will be based on the following data:**

- We select the number of loaded ICU per year: 7500 ICU after 31 pallet units
- The average distance that the FLT must pass: s = 165 m
- Average speed of FLT: v = 5 m / s

$t_1$ = 20s,

$t_2$ = 30s,

$t_3$ = 20s,

$t_4$ = 33s,
$t_5$ = 20s,
$t_6$ = 30s,
$t_7$ = 20s,
$t_8$ = 33s,

$M_d$ = 2 pallet units,
$T_{cp}$ = 11 hours,
ppd = 250 days,
r = 15 %

- Number of loaded ICU per year:

$$Q_{vr} = 7500 \text{ ICU x } 31 \text{ pallet units} = 232500 \text{ pallet units / yer} \quad (14)$$

- Time necessary to overcome the transport distance in the loaded state:

$$t_4 = s/v = 165 \text{ [m]}/5 \text{ [m.s}^{-1}\text{]} = 33 \text{ [s]} \quad (15)$$

- Average duration of the operational cycle of the mechanized device:

$$t_{cp} = 20 \text{ [s]} + 30 \text{ [s]} + 20 \text{ [s]} + 33 \text{ [s]} + 20 \text{ [s]} + 30 \text{ [s]} + 20 \text{ [s]} + 33 \text{ [s]} = 206 \text{ [s]} \quad (16)$$

- Hour performance:

$$Q_h = 3600 / 206 \text{ [s] x } 2 \text{ pallet units} = 34,9 = 35 \text{ [pallet units/hour]} \quad (17)$$

- Required daily performance:

$$Q_{vd} = 232500 \text{ pallet units} / 250 \text{ [days]} = 930 \text{ [pallet units /day]} \quad (18)$$

- Required hour performance:

$$Q_{vh} = 930 \text{ pallet units} / 11 \text{ [h]} = 84,5 = 85 \text{ [pallet units /h]} \quad (19)$$

- Operational necessity:

$$Z_p = (85 \text{ pallet units x } 206 \text{ [s]}) / (3600 \text{ x } 2 \text{ pallet units}) = 2,43 = 3 \text{ mechanized devices (FLT)} \quad (20)$$

- Total necessity:

$$Z_{cp} = 2,43 \text{ x } 1,15 = 2,79 = 3 \text{ mechanized devices (FLT)} \quad (21)$$

## 4. CONCLUSION

Determination of the proper number of handling devices has a major impact on labor productivity and it can greatly influence the prosperity of the whole organization.

The contribution was aimed precisely to determine the correct number of mechanized devices with the using of appropriate computational procedures. In the second chapter was first presented a model calculation of the required devices used in connection with the handling with ICU in intermodal terminals, concrete it was about stacking trucks Kalmar and subsequently in the third chapter there was pictured the procedure for the calculation of the

required handling devices used for loading of pallet units into ICU, thus the determination the number of forklift trucks.

## LITERATURE

[1] ADAMICOVÁ, E., KLAPITA, M. *Tovaroznalectvo, ložná a obalová technika.* Žilina: EDIS – vydavatelstvo ŽU, 2002. 187 s. ISBN 80-7100-981-4.

[2] K-Report, internetovské stránky českého dopravného servera, [online]. c2004-2009 [cit. 2010-11-25] Dostupné z : < http://www.k-report.net/>.

[3] ŠULGAN, M., RIEVAJ, V. *Ložné a skladovacie operácie – technika technológia.* Žilina: EDIS – vydavatelstvo ŽU, 2000. ISBN 80-7100-762-5.

[4] Projekt VEGA č. 1/0398/08: Znižovanie negatívnych externalít v cestnej doprave. KCMD ŽU Žilina. 2008-2010.