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SELECTION OF OPTIMAL TRANSSHIPMENT AND TRANSPORTING MEANS FOR CONTAINERS MANIPULATION

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Key words: *Transshipment, technology, planning, SAW, model*
Abstract: *Transshipment is an essential part of the transport of goods. The transition to intermodal transport systems has significantly determined the development of the transshipment systems as a whole. Requirements for their unification, typing, and standardization create the necessary conditions for the automation of transshipment in all its segments. In this paper, vertical and horizontal technologies are differentiated, their basic characteristics, profitability and feasibility, and other details are compared. After a comparative analysis, a model of choosing the appropriate technological solution was proposed through the evaluation of the most frequently used transshipment technology based on the most important criteria for means with cyclical action. The key to designing the terminal is that the technology corresponds to the intended capacity of the terminal and that for this capacity has the best ratio of capacity-price. Also, one should bear in mind the possibility of further enlargement regarding the constant growth of goods traffic. To select the appropriate technology, the SAW method was selected. The relative relations of the key parameters of the different alternatives are shown, and their normalization was performed. Also, the dimension matrix with which the analyzed technologies were ranked was formed. The proposed model can usefully serve anyone involved in the planning of transportation technology in logistic centers, from the aspect of capacity and labor costs.*

INTRODUCTION

Defining the most favorable typical technology is solved by applying a systemic analysis of type solutions to certain classes of transshipment tasks which application is common in practice. So, the processing of the formed set of variants of technological solutions is basically based on the analysis of the effects of applying different typical technologies to the concrete analyzed process. Through the selection of typical technology, the technological elements - the means of mechanization to be used are not determined at the same time, and the choice of the medium with the best technical-exploitation characteristics represents an important place for rationalization.

Prior to the selection, it is necessary to carry out a framework distribution and analysis of the means of mechanization as well as the conditions of exploitation through: analysis of the technological and technical characteristics of the means (speed, load capacity, handling, operation, etc.), type, shape and mass of the handling unit or freight unit , selecting the drive and load capacity, floor loading of storage ramps, manipulating terminal surfaces, selecting the type of catching device, selecting the asset from the aspect of environmental impact and vice versa, etc. Each of these conditions requires detailed analysis as well as mutual alignment.

The starting points for the selection of the transshipment means are handling units and loading units with their characteristics, size, content, form, quantity, and others. Adaptation of the catching bodies to the technological requirements is relatively easy to implement because there is a whole range of carrying capacity and even a greater number of different catching organs (forks, spreaders, side grips, thorns, hooks, etc.).

COMPARATIVE ANALYSIS OF CONTAINER CRANES AND CONTAINER CARRIER TRUCKS

In the case of road-rail terminals, it can be said that gantry cranes are usually the basic structural element of the transshipment and storage systems. Of course, these cranes also occur in port terminals, but as a rule, they are combined with other technological elements. Earlier, in the design and development of road-rail terminals, transshipment technology implied the use of railroad cranes and carriers' trucks. Now, the portal cranes represent a basic technological family, while the carrier trucks represent auxiliary manipulative means used to deployment the containers within the terminal and belong to the group of auxiliary machinery. [1]:

- *CSC-Container Straddle Carrier* [2], *UC-UanCarrier* [3, p. 132] [4], *ECS ECS W, SH Shuttle carrier),* on rails RMCGC (Rail Mounted Container Gantry Crane), or on RTCGC (Rubber Tyred Container Gantry Crane),
- Multifunctional forklift trucks (*FLT-ForkLift Truck*) [5];
- Multifunctional side loaders (*SL-Side Loader*) [6];
- Telescopic handlers (*RS*) [7];

In Table 1, a comparative analysis of the advantages and disadvantages of cranes with pneumatic wheels and rail cranes is given. In road-rail container terminals, a number of variants of gantry cranes are used. The concepts applied to different work volumes are different in terms of both the design and the width of the range. They are built according to the technological conditions of the terminals on which they are installed.

Table 1. Comparative analysis of cranes on pneumatic wheels and rail cranes

RTCGC on pneumatic wheels		RMCGC - Rail cranes	
Advantages	Disadvantages	Advantages	Disadvantages
Lower investment	It engages a large surface	A small need for space	Great investment
Great flexibility	Long transport routes	Great capacity	The plant is fixed
Covering many tracks	It disturbs other capacities	Good selectivity	It covers only certain tracks capacities
Greater storage capacity	Poor visibility	There is no disturbance of the transshipment device and other modes of transport	Limited storage capacity
Significant ability to provision capacity	High noise level	Low noise, good visibility	Adverse reservation of capacity

The second generation of gantry cranes introduces the use of a special form of trolleys with a catching device that allows the container to be transshipped from the railway wagons beneath the contact network for feeding the locomotive in the event of an electric train (Figure 1).

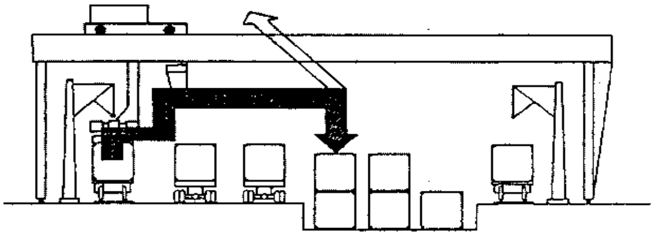

Fig. 1 The second generation of gantry cranes for container handling **[3]**

It is important to emphasize that, as with forklifts for manipulating the containers, the container cranes use different versions of the locking devices. The most commonly used are spreaders, but the way of their connecting with the trolleys can have different constructive solutions.

Although in case of the road-rail container terminals the most frequently gantry cranes are used for the containers handling, this does not mean that the frame cranes are the only right choice as the means of transshipment mechanization. Earlier, German DEMAG has developed a study of various transshipment concepts in road-rail container's terminals. Some alternatives are analyzed in search of an optimal solution [8]. The following alternatives were analyzed (Figure 2):

- **A1.** A free portable RMCGC with side-mounted combined lifting equipment on the telescope with the action from above;
- **A2.** Single boom RMCGC with a hook. Portal rail crane with one overhang and supporting combined equipment with the action from above;
- **A3.** A sloping rail track with a suspended track and a combined grip device whose guide describes the X-track;
- **A4.** A telescopic crane with a combined gripping device with a wearing principle like for forklifts;
- **A5.** Cantilever rail track hoist with four pillars with combined equipment; and
- **A6.** Cantilever rail track hoist with two pillars based on the solution applied in racking lifts in rack warehouses with combined equipment, Cantilever railroad hoist with four pillars with combined equipment.

An interesting excerpt from this project is the comparison of alternatives from the technical and technological aspect, i.e. from the aspect of the degree of satisfaction of the relevant technical and technological criteria. A comparison was made using the method of effectiveness analysis. The relative relationship of the parameters observed in these alternatives is given in table 2. Based on the characteristics of typical mechanization and average technological times in individual terminals in the world, table 2 gives an overview of the load capacity, the average cycle time by type of operation, average capacity in the number of the containers per hour and the average number of manipulations in shifts.

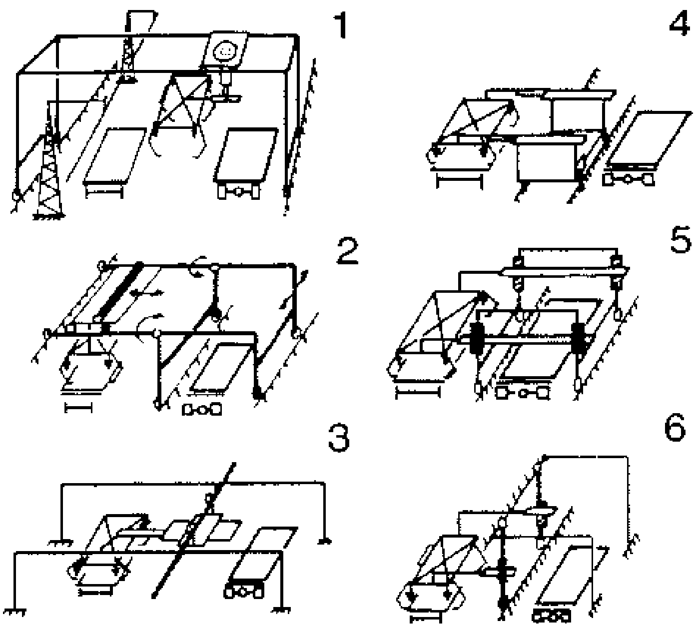

Figure 2. Different variants of cranes for manipulating containers [8]

Table 2. Duration of cycle and capacity of typical means of mechanization [3]

No.	Resource	Load capacity (t)	Means to means (s)	Means to warehouse and vice versa (s)	By warehouse (s)	Capacity (cont./h)	The average number of manipulations per shift
1	Gantry crane	31.4	240	360 at l=20m	360 at l=20m	11-15	188-120
2	Portal crane with overhangs	39.2	360	400 at l=20m	400 at l=20m	8-11	64-88
3	Side loader	49-50.0	-	480 at l=50m	600 at l=20m	6-8	48-64
4	Front loader	7.8-38.0	-	500 at l=50m	600 at l=50m	6-8	48-64
5	Manipulator	29.4	720	480	-	5-8	40-80
6	Truck mounted crane	31.4	300	360	360	10-11	80-88

Choosing the appropriate resources is very complex especially from the aspect of possible alternatives that are subject to analysis: technical, technological, economic, organizational criteria, etc.

MODEL OF THE SELECTION OF APPROPRIATE RESOURCES

The technical and technological criteria are the most important when choosing the appropriate transport and manipulation system. Economists say that investment and exploitation costs for individual variants they are more significant. They cannot be used at the stage of lump or orientation development of variants, but only in specific cases. It requires carefulness in the sense that the analysis does not involve an inaccurate level of costs. The necessary prerequisite for the optimal choice of transport manipulative means, ie a favorable combination, is the formation of a detailed matrix Technological requirement - Technological element, taking into account all start-end points: stops, where the means receives and delivers the load, the topology of the transport path, load capacity, height and width of passages, dimensions and mass of cargo, required transport capacity, as well as the exact order of execution of transport operations for each type of cargo. Based on the technical and technological characteristics, the alternative criteria are classified into three areas:

- realization,

- performance, and
- compatibility.

Assigning values to criteria, as well as weighting weights of the criteria, were performed expertly, i.e. based on the knowledge of the characteristics of each of the alternatives and their fulfillment of the set criteria. It is considered that it is better to apply a scoping scale range of 1-5 than 1-10.

Multi-criteria decision-making is a decision-making method which is used in the case of multiple criteria, which can often be conflicting with one another. The problem of multi-criteria decision-making can be divided into two phases [9]:

- multi-criteria ranking: MADM (Multi-attribute decision making), methods ELECTRE, TOPSIS, PROMETHEE, SAW, etc.),
- multi-criteria programming: MODM (Multi-objective decision making).

Multi-criteria ranking is the selection of an optimal alternative from a set of alternatives in the case of multiple criteria. In this ranking, the target functions are embedded in the attributes, with the number of alternatives being final and presented discreetly. SAW (*Simple Additive Weighting*) It is a simple and well-known method of multi-criteria analysis which considers the weights of criteria. For each alternative (A), the aggregate characteristic, i.e. the value obtained by summing the weighted normalized values by all criteria, is calculated. The alternative to which corresponds to the largest such calculated value represents the "best" solution.

$$A^* = \left\{ A_i \mid \max_i \sum_{j=1}^{n} W_j^{'} r_{ij} \right\}$$

where r_{ij} are the normalized values from the matrix, in accordance with the previously shown normalization modes.

$W_j^{'}$ is the normalized value of the weight coefficient W_j:

$$W_j^{'} = \frac{W_j}{\sum_{j=1}^{n} W_j}$$

Because very expensive complexes are considered, the proper choice of the solution of the realization of the transshipment tasks connected with the container lifting cranes is essential.

In most cases, cranes represent the backbone of the transshipment machinery for road-rail container terminals. In practice, there are cases that the proper dimensioning of capacities (for the most part, the case of over-dimensioning) was not performed for various reasons. Considering six characteristic alternatives, certain conclusions and recommendations for the selection of a suitable variant in the function of the required capacity expressed in TEU units[1] are made. The non-dimensional matrix is obtained by putting in the relation of the value of the criteria (normalization of the criteria), table 3.

Table 3. Relative relationship of parameters of different alternatives

Field		Realization			Operating characteristics				
Criteria / Alternatives		Required area	Ergonomic factors	Modularity	Turnover (capacity)	Flexibility	Storage facilities	Reliability	Compatibility
Alternatives	A1	7	9	6	7	7	10	9	8
	A2	1	8	1	8	10	5	7	6
	A3	3	6	9	7	1	8	8	4

[1] TEU-twenty feet equivalent unit

	A4	8	4	10	2	5	2	6	1
	A5	2	2	3	10	3	10	2	9
	A6	7	10	8	8	8	2	9	8
Weight coefficient		0.9	0.75	0.85	0.8	0.7	0.85	0.9	0.9

The weighting of the criterion is done according to their importance for decision-making, which is adapted according to the expert's assessment (for example K1=0.9; K2=0.75; K3=0.85; K4=0.8; K5=0.7; K6=0.85; K7=0.9, and K8=0.9). After acting of weightings on individual values of the criteria (by multiplying the weight values and the normalized values of the criteria) and adding the obtained products by variants, the order of the considered variants is shown in table 4.

Table 4. Non-dimensional matrix

Field		Realization			Operating characteristics				Compa-tibility	**Sum**
Criteria / Alternatives		Required area	Ergonomic factors	Modularity	Turnover (capacity)	Flexibility	Storage facilities	Reliability		
Alternatives	A1	0.118	0.102	0.077	0.084	0.074	0.128	0.135	0.120	**0.838**
	A2	0.017	0.090	0.013	0.096	0.105	0.064	0.105	0.090	0.580
	A3	0.051	0.068	0.115	0.084	0.010	0.102	0.120	0.060	0.610
	A4	0.135	0.045	0.128	0.024	0.053	0.026	0.090	0.015	0.516
	A5	0.034	0.022	0.038	0.120	0.032	0.128	0.030	0.135	0.539
	A6	0.118	0.113	0.102	0.096	0.084	0.026	0.135	0.120	0.794

For selected criteria, the alternative A1 is best ranked - the value of the sum of all criteria is 0.838. Weights can also take other values depending on the criteria set.

CONCLUSIONS

Despite a large number of influential KPIs and constraints, the choice of potential solutions can be done by a comparative analysis of the good and bad properties of individual systems, as well as by comparing each other. This approach of comparing different system variants and selection criteria is generally accepted in decision-making processes since the decision-making process itself requires respect of technical, time and cost constraints. An analysis of an excessively large number of combinations (criterion — system) is not in principle useful, as practice confirms that the solution sought is, as a rule, in the set of solutions most commonly used in practice and which are often defined as typical technological solutions. In the paper, an evaluation of the technological systems using the SAW method was done successfully. It is recommended that in the planning of a certain material flow system, the importance of different decision criteria is further assessed in order to take better account of their impact on the fulfillment of set goals related to the system that is the subject of planning.

References

[1] Alamy, "Container carrier truck loading a container, transportation, logistics, illustration," Alamy, 10 09 2013. [Online]. [Accessed 30 05 2019].

[2] Kalmar, "Straddle Carriers," Kalmar, 2018. [Online]. Available: https://www.kalmarglobal.com/equipment/straddle-carriers/. [Accessed 30 05 2019].

[3] B. Davidović, Tehnologije kombinovanog transporta, Beograd: VEDES, 2012.

[4] R. C. Scott and T. F. Peeper, "Economic Returns from Broadleaf Weed Control in Hard Red Winter Wheat (Triticum aestivum)," *Weed Technology*, vol. 8, no. 4, pp. 797-806,

1994.

[5] Ref 3.22, "Operation of Fork Lift Trucks," 18 09 2017. [Online]. Available: https://www.ulster.ac.uk/__data/assets/pdf_file/0013/143410/FLT.pdf. [Accessed 30 05 2019].

[6] n.d., "Combilift Combi SL Side Loader Forklift," Wisconsin Lift Truck Corp., 2019. [Online]. Available: https://www.wisconsinlift.com/product/combilift-combi-sl-side-loader-forklift/. [Accessed 30 05 2019].

[7] Evocon, "Telescopic handlers," 2019. [Online]. Available: http://www.evocon.rs/files/Manitou_MT_X_14_18_EN.pdf. [Accessed 30 05 2019].

[8] n.d., Stručno mišljenje o horizontalnom sistemu pretovara kontenera, Beograd: Saobraćajni fakultet, 1991.

[9] D. Tadić, Operaciona istraživanja u upravljanju proizvodnjom, Kragujevac: Fakultet inženjerskih nauka, 2009.

ИЗБОР НА ОПТИМАЛНИ ПРЕТОВАРНИ И ПРЕВОЗНИ СЪОРЪЖЕНИЯ ЗА ОБРАБОТВАНЕ НА КОНТЕЙНЕРИ

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СЪРБИЯ

Ключови думи: *претоварване, технология, планиране, модел SAW*

Резюме: *Претоварването е важен етап от процеса на транспортиране на стоки. Преминаването към интермодални транспортни системи е определило в значителна степен развитието на транспортната система като цяло. Изискванията за унифициране и стандартизиране създават необходимостта от автоматизиране на претоварните процеси на всеки един етап от превоза. В настоящия доклад е извършено сравнение на хоризонтални и вертикални системи за претоварване в зависимост от тяхната гъвкавост, ефективност и ключови характеристики. В резултат на сравнителен анализ е предложено подходящо технологично решение на база оценка на широко прилаганите претоварни технологии при наличие на циклични процеси. Ключово значение за изграждането на съответния интермодален терминал има неговия потенциален капацитет и какво е съотношението между цена и капацитет. Също така трябва да се вземе предвид и възможността от бъдещо разширение на терминала при увеличаване на товарния трафик. С цел да се подбере подходяща технология, се прилага методът SAW. Представена е зависимостта между ключови параметри. Създадена е матрица, в която са ранкирани избраните показатели. Предложеният модел може успешно да се използва от всеки, който извършва изследвания в областта на планиране на транспортните процеси в логистични центрове от гл. т. на капацитет и разходи за труд.*