The Optimization of the Intermodal Terminals
Optimizacija intermodalnih terminala

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DOI 10.17818/NM/2015/SI2
UDK 656.021
Original scientific paper / *Izvorni znanstveni rad*
Paper accepted / *Rukopis primljen:* 6. 3. 2015.

Summary

This paper deals with the optimization of intermodal terminals. The optimization is discussed in two areas, which are the optimization of transport operations in an intermodal terminal and an optimal location of intermodal terminals on a particular territory (in a particular state).

KEY WORDS

intermodal transport
intermodalterminal
optimization of activities
CPM method (Critical Path method)
multi-criteria evaluation method

Sažetak

U ovom radu govori se o optimizaciji intermodalnih terminala. O optimizaciji se raspravlja u dva područja, a to su optimizacija prijevoznih operacija na intermodalnom terminalu i optimalna lokacija intermodalnih terminala na određenom teritoriju (u određenoj državi).

KLJUČNE RIJEČI

intermodalni prijevoz
intermodalni terminal
optimizacija aktivnosti
CPM metoda
metoda multikriterijske procjene

INTRODUCTION

An intermodal terminal (i.e. IT) forms one of the most essential elements of the intermodal transport infrastructure where the individual means of transport meet. It represents a systemic point of transport mode shift, when handling some of the intermodal transport units (a large ISO container, a swap-body, a road semi-trailer, combinationof vehicles, a bimodal trailer), and enables co-operation of all the involved means of transport.

The intermodal terminal provides a whole range of services that are related to transportation of the intermodal transport units (i.e. ITUs). This particularly concerns the supply and distribution of the ITUs (by rail, road or water), handling the ITUs, or alternatively, their storing in a storage area.

The intermodal terminal's equipment must meet the basic requirements of the parties involved (carriers, shippers, freight forwarders, operators) and should also comply with the requirements of the European Agreement on Important International Combined Transport Lines and Related Installations (the AGTC Agreement).

THE THEORETICAL BACKGROUND FOR THE OPTIMIZATION OFTHE TECHNOLOGICAL OPERATIONS IN IT

The AGTC Agreement states that there must be ensured a minimum time period from the latest time of acceptance of goods to the departure of trains as well as from the arrival of trains to the availability of the ITUs ready for the transshipment onto a road vehicle for the efficient handling of consignments in intermodal terminals. This period shall not exceed one hour, unless the wishes of the customers regarding the latest time of acceptance or disposal of the ITUs can be complied with by other means. This implies that this is the period between the acceptance of the ITUs for loading and the departure of trains from the IT, or more precisely, the period from the arrival of trains to the IT to the availability of the ITUs ready for the unloading, in terms of the technological operations in an IT [1], [2].

It is possible to use graph theory methods, namely a method of critical path analysis for the optimization of such operations. Their asset is their simplicity and illustrative nature. The solution obtained through them is well used in practice. The most famous and the most used of these methods are known as the CPM (Critical Path Method) and the PERT (Program Evaluation and Review Technique). Both methods optimize only one agent: time, and hence are also sometimes called the time planning methods. In fact, the CPM and PERT methods merely differ in their approach to detecting the duration ofthe individual operations, i.e. the network evaluation. [1], [2]

The CPM Method presupposes that there is a precisely set period of its duration for each operation; thus the CPM method is a deterministic reality model. The PERT Method presupposes that the duration of an operation is a random variable, described by means of a certain probability distribution (the most commonly used is the β-division).

The actual calculation of the critical path is the same for both methods. It works with a network which is assumed to be acyclic and its edges head from the nodes with a lower index to the nodes with a higher index. For each operation we have one figure about its duration. For the CPM Method it is the fixed estimate y_{ij}, for the PERT Method it is a figure of the average duration $\tilde{y}_{ij}$.

For other quantities it is possible to introduce the following markings:

t_{i0} – the earliest possible commencement of operations coming out of i,

t_{i1} – the latest possible moment of termination of operations finishing in nod i,

$t_{i0} + y_{ij}$ – the earliest possible termination of operations (i, j),

$t_{i1} - y_i$ – the latest possible commencement of operations (i,j).

Since not only the length of the critical path and its progress, but also the time reserves of other operations are important during a figure calculation, the actual calculation takes place according to these relations:

$$t_{10} = 0 \quad (1)$$

$$t_{j0} = max_j\,(t_i^0 + y_{ij}) \quad (2)$$

in the direction from the inlet to the outlet and

$$t_n^1 = t \quad (3)$$

$$t_i^1 = min_j\,(t_i^1 - y_{ij}) \quad (4)$$

in the direction from the outlet to the inlet.

The total reserves of all the operations are calculated, and marked as RC_{ij}, based on these qualities and they are calculated according to the formula:

$$RC_{ij} = t_j^1 - t_i^0 - y_{ij} \quad (5)$$

Additionally, the critical path is formed by those operations whose total reserve equals to 0. It is then necessary to design the technology of the operations so that the total time of the operations located on the critical path is no higher than the maximum set period (e.g. 60 minutes - AGTC) [3].

SPATIAL ALLOCATION OF PUBLIC ITs

The previous IT spatial allocation methodologies worked on the assumption of possible potential and even distribution of ITs within a geographical arrangement. This decision making is not yet considerably objective (even if it may be correct) as it does not include an optimization criterion. At present, there are several mathematical optimization methods seeking a suitable, or rather, an optimal IT location based on a certain optimization criterion.

The issue of the IT spatial allocation may be characterized in general as an issue of locating service centres on a network. The overall transport performance of road collection and distribution of the ITUs depends on the number and location of the ITs. However, the optimization criterion is to minimize the overall transport performance of the collection and distribution described in thousands of tkm, since the IT allocation needs to be based on the intermodal transport potential described in thousands of tons. There are several optimization methods and algorithms in order to deal with such tasks [4] - [6]. An optimal IT location is, in a way, a specific case. Designing a methodology of establishing the optimal number and location of an IT is a complex issue where a number of factors determining the choice of the IT location must be simultaneously taken into account.

First of all, when forming a mathematical model of the IT spatial allocation, it is necessary to consider the size of the potential, which is situated in its catchment area. The locating of an IT in a particular place is inefficient without a sufficient load. It is also necessary to consider the performance of the existing ITs and the transshipment points that have already been built. The issue of the IT location cannot be solved by simply placing the matter on the so called "Greenfields", as the existing transport infrastructure needs to be taken into consideration. That means locating the ITs in the places with a good connection to the road and rail network [4], [7].

The intermodal terminals will therefore be placed on a particular transport network. The basis of this transport network will consist of the road network, because it solves the problem of minimizing the costs of collection and distribution within the catchment areas. In terms of the real possibilities of solving the task, its being of a large extent, as well as the required quality of the road infrastructure, it is not necessary to consider the entire road network. The considered road network will comprise of motorways, main roads and A- and B-roads. This transport network is represented by a graph structure, where the finite set of significant points is called the vertices and the finite set of lines, connecting some vertices and the representing communication links, is called the edges. The simplest graph structure (that is made up of non-oriented edges) is the graph in this case. The vertices in the transport network will form the intersections of the roads, the completed roads or the other important points. The points (places) where the possible transport potential is situated or rather formed will be particularly important. Such potential is mostly found nearby or directly in larger and important cities. Apart from the large and important road intersections, the network vertices will thus be the important cities as well. All the major district towns (the prerequisite for the existence of potential sources for intermodal transport) and other towns may be considered as the basis. They are also important due to the existence of the potential sources and their geographical location [7].

Each vertex in the network will be assigned a non-negative number (the so-called vertex weight) which will express the importance of the given vertex. The edges will represent the road sections connecting two adjacent vertices in the examined transportation network. Each edge will be evaluated by a non-negative number which will describe the length of the given edge, i.e. the kilometer distance between two adjacent vertices.

The role of the mathematical model is to select from a certain (final) number of vertices (theoretically appropriate), such that best suits the location of an intermodal terminal. Considering the above factors, it affects the choice of an IT location in the particular vertex, and that should be considered when designing the methodology. Then the group of the multi-criteria evaluation methods appears to be as the most appropriate one to use when evaluating the vertices.

The multi-criteria evaluation methods may generally be used when comparing and subsequently selecting any objects (e. g. the ITs) based on several indicators. Owing to their ability to synthesize several different indicators (characteristics) into a quantitatively expressed comprehensive indicator, these methods are particularly appropriate for an analysis of an object´s (an IT´s) place on the market (network). They enable to compare a set of several objects based on the multiple characteristics of their operations and at the same time to determine the order of the analyzed objects location. Then the selection of the objects is given by the order they reached after taking allof the selected characteristics into account.

The basis of the multi-criteria evaluation is the starting matrix of objects and their characteristics. The objects represent the places (vertices) suitable for location of the intermodal terminals. Their characteristics will be expressed by technical and technological indicators. This means that the comparison will involve the indicators of places (vertices) that may decisively affect the IT location, i.e.the general criteria for the IT allocation.

When constructing the starting matrix of these objects, it is necessary toadhere the following steps:

1 - to choosethose objects included in the analyzed set.
2 - to select those indicators characterizing the object´s activity.
3 - to choose the weights of indicators.
4 - to form the starting matrix (*table 1*).

The multi-criteria evaluation methods aim towards transforming and synthesizing the value of the various indicators into a single complex indicator (a resulting characteristic), comprehensively expressing the level of the individual objects in a set of the studied objects. Given the fact that none of the multi-criteria evaluation methods sufficiently depicts the specifics of the studied issue, the most favorable method to use seems to be the partly modified method of the weighted sum of order with the evaluation of the characteristics of standardized weights.

The Legend of the Matrix:

X_{ij} – a figure of the j-th indicator in the i-th object,
m – anumber of the indicators,
n – anumber of the evaluated objects,
p_j – the weights which may be:

- ministandardized, meeting the condition $0 \leq p_j \leq 1$; $j = 1,2,...m$; where $p_1 + p_2 + ... + p_{m-1} + p_m = 1$,
- differentiated, integers expressing the weight of each criterion.

The comprehensive indicator is the overall level (importance) expression of the given vertex or rather thesuitability for an IT location.

The summary indicator: a vertex coefficient, by which its weight (importance) is assigned, is calculated as the sum of products of weights of the individual criteria and selected criterial indicators:

$$K_i = \sum_{j=1}^{m} p_j . s_j \tag{6}$$

where:

K_i – a coefficient of the i-th vertex, i = 1, 2, ..., n,
n – a number of vertices in network,
p_j – the standardized weights of the individual criteria, $\sum p_j = 1$,
m – a number of criteria,
s_{ij} – the criterial indicators.

Hence, the summary indicator will express the importance of the studied vertex and it will have a substantial impact on determining the IT location into the given vertex. Therefore, it is important to choose such characteristics (indicators) that best describe the specifics of this particular matter. Thus it takes account of all the factors that influence and requires the choice of the IT location into the given vertex.

The issue of locating the intermodal terminal seeks the answers to two fundamental questions, namely what the optimal number of the intermodal transport terminals is and where these transport terminals will be located. There are methods and algorithms that simultaneously search for the answers to both of the questions; thus they find out the optimal number as well as the location of the ITs (e.g. the Branch and Bound Method), then those methods that only find the optimal number of the ITs(the Method of Continuous Approximation) or, on the contrary,the optimal IT location specified by their

Table 1. Formation of the objects´ starting matrix

Indicator / Object	X_1	X_2	.	X_j	...	X_m
1	X_{11}	X_{12}				X_{1m}
2	X_{21}	X_{22}				X_{2m}
"				"		
i				X_{ij}		
"				"		
n-1	$X_{n-1,1}$	$X_{n-1,2}$				$X_{n-1,m}$
n	X_{n1}	X_{n2}				X_{nm}
Weights of indicators	p_1	p_2		p_j	...	p_m

Source: authors

number (the Iterative Method). Using either of these methods depends on the accuracy of the solution, which is required on the input data that are available or on the time-consumption [3] - [6].

CONCLUSION

An inevitable prerequisite for thedevelopment of intermodal transportin the current conditions of the European transport system is its competitiveness, especially against the direct road haulage transport. The competitiveness is mainly ensured through the speed of traffic, its accuracy and its reliability. The intermodal terminals significantly affect these factors,particularly due to their position and theiroperational technology.

The location of the intermodal terminals affects the intermodal transport availability not only for the end customers (the carriers), but also for road hauliers, shippers and operators and this is especially true regarding European continental intermodal transport. The right IT location affects the delivery time of a product, which is currently a very important indicator in the logistics approach.

The operating technology of the intermodal terminals influences the totaltime that a consignment spends in the IT and thus it also affects the transporting speed, the accuracy and the consignment´s delivery timeliness [4], [6], [7].

The IT location as well (as the IT´s operational technology) may be rationalized, or more precisely,optimized by using several appropriate mathematical optimization methods, that will make the intermodal transport become competitive. It is possible to assume from its development thatit is necessaryat present in order to ensure the sustainable development of the transport system in the European area [7].

REFERENCES

[1] Buzna, Ľ. *Návrh štruktúry distribučného systému pomocou spojitej aproximácie a diskrétneho programovania*. Dissertation. Žilina: Žilinská univerzita v Žiline, Fakultariadeniaain formatiky, 2003.

[2] Daněk, J., Teichmann, D. *Uplatnění matematických metod v kombinované přepravě*. In: Logistika, 10/2003.

[3] Ližbetin, J. *Návrh systémových opatrenína rozvoj kombinovanej dopravy v Slovenskej republike*, Dizertačnápráca. Žilina: Žilinská univerzita v Žiline, Fakulta prevádzkya ekonomiky dopravy a spojov, 2006.

[4] Cenek, P., Klima, V., Janáček, J. *Optimalizace dopravních a spojových procesů*. Žilina:Vysoká škola dopravy a spojov v Žiline, Edičné stredisko VŠDS, 1994.

[5] Černý, J., Kluvánek, P. *Základy matematickej teórie dopravy*. Bratislava: VEDA vydav. Slovenskej akadémie vied, 1991.

[6] Kubasáková, I., Kampf, R., Stopka, O. *Logistics information and communication technology*. Communications, Vol. 16 (2), pp. 9 – 13, ISSN1335-4205. 2014.

[7] Stopka, O., Kampf, R., Kolář, J., Kubasáková, I., Savage, Ch. *Draft guidelines for the allocation of public logistics centres of international importance*. Communications, Vol. 16 (2), pp. 14 – 19, ISSN: 1335-4205. 2014.