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SELECTED ASPECTS OF COSTS SHAPING IN THE INTERMODAL TERMINAL

Roland Jachimowski

Warsaw University of Technology, Faculty of Transport
Koszykowa Street 75, 00-662 Warsaw, Poland
tel.: +48 22 2341410
e-mail: rjach@wt.pw.edu.pl

Abstract

The article presents the problems of designing intermodal terminals from the point of view of expenditures on construction and equipment as well as costs of its operation. The scope of factors to be considered at the design stage of the intermodal terminal was determined. The principles of calculation of expenditure on terminal infrastructure are presented. Based on these expenditures, the principles of calculating the cost of maintenance of equipment and labour are outlined. In addition, the practical examples of determining the cost of operation of handling equipment and labour costs are presented. The terminal carries out the functions of transhipment of intermodal transport units between means of transport, belonging to different modes of transport and the operations on these units in connection with their storage. Due to the different types of external means of transport operated in the intermodal terminal, a sufficient number of rail tracks, roads lines, storage, and handling areas should be provided. Apart from expenditures and costs, an important element in the design of an intermodal terminal is its location in the logistics network.

Keywords: *intermodal terminal, container, TEU, costs*

1. Introduction

The intermodal terminal is a spatial object with the given organization and infrastructure to handle intermodal transport units (ITU). The terminal carries out the functions of transhipment of intermodal transport units between means of transport, belonging to different modes of transport and the operations on these units in connection with their storage [4, 12]. The technology of the terminal operations and the functions performed in the intermodal transport system determine its shape and technical and human potential. In addition, the shape of the terminal is determined by the size of the area allocated to its location and by the number of JTI being served [14].

The design of the intermodal terminal is a difficult task, as it requires determining the flow of intermodal transport units (ITUs) through the terminal. It is necessary to determine the average ITU flow and the measurable flow that will take into account the periodic fluctuations. The type of intermodal units to be serviced will be used to determine their handling system (horizontal, vertical transhipment or both) [9, 11].

Due to the different types of external means of transport operated in the intermodal terminal, a sufficient number of rail tracks, roads lines, storage and handling areas should be provided. Hence, the configuration of terminal functional areas requires taking into account [13]:
– rail and road areas,
– handling operations areas,
– long and short-term storage areas,
– types and number of handling equipment,
– other terminal's equipment, e.g. fire protection in accordance with current regulations and requirements, safety systems, environmental protection systems.

The above rules for the design of intermodal terminals have to be considered from the point of view of the costs incurred for the terminal construction and equipment as well as the cost of its operation. Expenditure on the terminal is not only the cost of its construction, but also the cost of purchasing a plot. Therefore, the size of the area to be invested will be determined by the terminal configuration, UTI storage technology, or even the height of the UTI stacking in the storage area.

2. Expenditures and costs in the intermodal terminal

The concept of expenditures and costs are often used interchangeably in the literature. In practice, the expenditures will be understood as a factor determining the start and conduct of a given activity. In turn, the cost is defined as the physical and natural consumption of fixed assets, services, and human labour, expressed in monetary units, in order to obtain the effects measured in a given analytical period [1, 15].

Expenditures and costs are the basic criterion for evaluation of the quality of the cargo handling facility-designing project [2, 10]. An example of such a facility, where the subject of transhipment is ITU is the intermodal terminal. Expenditures on the intermodal terminal are the result of the expenses to be incurred for the installation of the necessary infrastructure, equipment and systems to ensure the implementation of the terminal processes [5, 6, 8, 17].

Expenditure on infrastructure mainly concerns the construction of the track system, concrete container storage areas, operating areas for loading equipment, parking lots, water and power installations, roads, maintenance buildings for equipment and containers, as well as administrative buildings or terminal management systems [16].

Expenditures on transport equipment include all types of loading equipment that can be used at the terminal (cranes, reach stackers) as well as systems supporting the loading equipment operation (e.g. The system that controls the RMG crane lane). These expenditures in the case of an intermodal terminal are a key component of the funds as they are necessary to purchase this equipment.

The costs in the intermodal terminal can be divided into fixed and variable costs. The division remains valid short periods, since for long periods costs can vary [7].

Fixed costs are the costs independent of terminal turnover, provided that the turnover does not necessitate a change in employment by increasing or decreasing the number of employees. Consequently, fixed costs will include staff salaries or costs of periodical maintenance of terminal infrastructure

Variable costs are directly related to the terminal turnover expressed in the number of intermodal units serviced. These costs mostly relate to energy consumption, equipment, etc.

Determining the terminal's operating costs mainly relies on an analysis of historical data about the structure of the tasks performed and the associated costs. When there is a lack of such a data, the methods of estimating inputs and costs should be used at the terminals in design phase.

3. Expenditures calculation

Intermodal terminal expenditures include the infrastructure, terminal management systems, and loading equipment [3]. Expenditures on infrastructure, transport equipment, and terminal support systems are expressed in the form of:

$$E = E_I + E_{UT} + E_W \,, \tag{1}$$

where:
E_I – expenditures on terminal's infrastructure [PLN],
E_{UT} – expenditures on terminal's equipment [PLN],
E_W – expenditures on systems supporting terminals and equipment [PLN].

Infrastructure expenditures includes:

– rail tracks, E_{tk} [PLN]:

$$E_{tk} = L_{tk} \cdot c_{tk} \,, \tag{2}$$

where:
L_{tk} – rail tracks length,
c_{tk} – rail tracks 1 meter cost;

– rail tracks crossings, E_{rk} [PLN]:

$$E_{rk} = n_{rk} \cdot c_{rk} \,, \tag{3}$$

where:
n_{rk} – number of rail tracks crossings,
c_{rk} – rail tracks crossings cost;

– roads, E_{dr} :

$$E_{dr} = P_{dr} \cdot c_{dr} \,, \tag{4}$$

where:
P_{dr} – road area [m^2],
c_{dr} – road area 1 square meter cost;

– storage area, E_{ps} :

$$E_{ps} = P_{ps} \cdot c_{ps} \,, \tag{5}$$

where:
P_{ps} – storage area [m^2],
C_{ps} – storage area 1 square meter cost.

Expenditures for loading equipment can be identified for vertical loading equipment (cranes) and for horizontal equipment (reach stackers, etc.). For the purposes of the study, the set of types of loading equipment used in the terminal may take the following form:

$$\boldsymbol{MT} = \{1, \ldots, mt, \ldots, MT\},$$

where MT is the set $\boldsymbol{MT}$ cardinality.

Hence, expenditures on loading equipment can be calculated from the following formula:

$$E_{UT} = \sum_{mt \in \boldsymbol{MT}} n(mt) \cdot c(mt) \,, \tag{6}$$

where:
$n(mt)$ – number of equipment of a type mt,
$c(mt)$ – cost of purchase of equipment of type mt.

4. Costs calculation

In addition to infrastructure and loading equipment, annual operating costs, including equipment and infrastructure maintenance costs and human labour costs, are an important factor in the economic analysis of the proposed transhipment terminal. These costs are expressed by the formula:

$$K_E^R = K_I^R + K_{UT}^R + K_L^R \,, \tag{7}$$

where:
K_I^R – annual costs of maintenance of terminal infrastructure [PLN/year],
K_{UT}^R – annual costs of maintenance of loading equipment [PLN/year],

K_L^R – annual labour costs [PLN/year].

The annual terminal's infrastructure maintenance costs are expressed by the formula:

$$K_I^R = K_{ST}^R + K_{SW}^R , \tag{8}$$

where:

K_{ST}^R – annual costs of maintenance of terminal's fixed elements [PLN/year],

K_{SW}^R – annual costs of maintenance of terminal's management system and systems supporting equipment operations [PLN/year].

Annual costs of maintenance of terminal's fixed element (rail tracks, roads, storage area, buildings, etc.) can be calculates as follows:

$$K_{ST}^R = E_I \cdot \gamma_I , \tag{9}$$

where γ_I is the cost factor of maintenance of terminal fixed elements [PLN/year].

Annual costs of maintenance of terminal's management systems as well as systems supporting equipment operations can be calculated as follows:

$$K_{SW}^R = E_W \cdot \gamma_W , \tag{10}$$

where γ_W is the cost factor of maintenance of terminal's management systems as well as systems supporting equipment operations [PLN/year].

In the case of intermodal terminal infrastructure, the cost factors relate to maintenance, inspection, repairs, etc., which condition the proper functioning of the infrastructure. The values of these coefficients should be determined on the basis of offers from providers of the given type of infrastructure, taking into account the services provided by them for the maintenance of that infrastructure.

5. Principles of calculation of loading equipment maintenance and labour costs

The costs of using transport and loading equipment are an economic criterion for their choice to carry out tasks in the intermodal terminal. They are usually calculated as the unit cost of moving 1 tonne of cargo on a particular distance.

Considering the possibility of using different types of loading equipment in the intermodal terminal, their annual maintenance costs are determined by the formula:

$$K_{UT}^R = \sum_{mt \in \boldsymbol{MT}} K_{UT}^R(mt) , \tag{11}$$

where $K_{UT}^R(mt)$ is the annual cost of maintenance of loading equipment of type *mt* [PLN/year].

The loading equipment maintenance cost includes:

– cost of depreciation of an equipment of type *mt*,
– costs related to the interest rate of foreign capital obtained for the purchase of an equipment of type *mt*,
– costs related to the interest rate of the own capital dedicated for the purchase of an equipment of type *mt*,
– repair and maintenance costs of an equipment of type *mt*,
– energy consumption costs of an equipment of type *mt*,
– costs depending on the performance of an equipment of type *mt*.

The cost of annual depreciation, and those related to the interest on the own and foreign capital acquired to purchase equipment, can be replaced by leasing costs.

Annual depreciation costs $K_a(mt)$ for the equipment of a type *mt* can be calculated as follows:

$$K_a(mt) = \frac{W_{pocz}(mt) - W_k(mt)}{d(mt)}, \tag{12}$$

where:
$W_{pocz}(mt)$ – initial value of an equipment of type *mt* [PLN],
$W_k(mt)$ – final value of an equipment of type *mt* [PLN],
$d(mt)$ – lifetime of an equipment of type *mt* [years].

Taking into account the actual consumption of equipment, related to the conditions and intensity of work and the quality of service, we could determine the value of the average depreciation cost factor for the equipment of type *mt*:

$$\alpha_1(mt) = \frac{W_{pocz}(mt) - W_k(mt)}{d(mt) \cdot E_{UT}(mt)}, \tag{13}$$

if $E_{UT}(mt)$ expenditures on terminal's equipment of a type *mt* [PLN], then annual depreciation cost of an equipment of type *mt* can be calculated as follows:

$$\gamma_A(mt) = \alpha_1(mt) \cdot E_{UT}(mt) \text{ [PLN/year]}. \tag{14}$$

Costs related to the interest rate of foreign capital $K_{oo}(mt)$ obtained for the purchase of an equipment of type *mt*, are determined by the formula:

$$K_{oo}(mt) = E_{UT}(mt) \cdot \gamma_1(mt), \tag{15}$$

where:
$E_{UT}(mt)$ – expenditures on terminal's equipment of type *mt* [PLN],
$\gamma_1(mt)$ – average annual interest rate factor on foreign capital for equipment of the type *mt*.

Costs related to the interest rate of own capital $K_{ow}(mt)$ obtained for the purchase of an equipment of type *mt*, are determined by the formula:

$$K_{ow}(mt) = E_{UT}(mt) \cdot \gamma_2(mt), \tag{16}$$

where $\gamma_2(mt)$ is the average annual interest rate factor on own capital for equipment of the type *mt*, resulting from the lost benefits of investing own capital.

Repair and maintenance costs $K_{nk}(mt)$ of an equipment of type *mt*:

$$K_{nk}(mt) = E_{UT}(mt) \cdot \gamma_3(mt), \tag{17}$$

where $\gamma_3(mt)$ is the cost factor of inspection and repair for the equipment of the type *mt*, in relation to the total cost of purchase and installation.

Electric energy costs $K_{E_{el}}(mt)$ of an equipment of type *mt*:

$$K_{E_{el}}(mt) = ZE_{el}(mt) \cdot k^{1\mathrm{kWh}}, \tag{18}$$

where:
$ZE_{el}(mt)$ – annual energy consumption of an equipment of type *mt* [kWh/year],
$k^{1\mathrm{kWh}}$ – energy costs [PLN/kWh].

Fuel costs $K_{E_{sp}}(mt)$ of an equipment of type *mt*:

$$K_{E_{sp}}(mt) = ZE_{sp}(mt) \cdot k^{1\mathrm{L}} \cdot h_{pracy}(mt), \tag{19}$$

where:
$ZE_{sp}(mt)$ – fuel consumption of an equipment of type *mt* [L/h],
$k^{1\mathrm{L}}$ – fuel cost [PLN/L],
$h_{pracy}(mt)$ – annual real number of equipment operating hours.

Leasing costs $K_l(mt)$ of an equipment of type *mt*:

$$K_l(mt) = \frac{d_l(mt)k_l(mt) + k_w(mt) + k_{wyk}(mt) - W_k(mt)}{d(mt)}, \tag{20}$$

where:
$d_l(mt)$ – leasing time [month],
$k_l(mt)$ – leasing instalment [PLN/month],
$k_w(mt)$ – initial fee connected with the transport and installation of an equipment of type *mt* [PLN],
$k_{wyk}(mt)$ – cost of repurchase an equipment of type *mt* [PLN],
$W_k(mt)$ – final value of an equipment of type *mt* [PLN],
$d(mt)$ – lifetime of an equipment of type *mt* [years].

The leasing time will be the same as the operating time when the equipment is not repurchased after the leasing period. In addition, in such a situation, the cost of the lease and the final value of the equipment should be omitted [5].

Costs depending on the performance of an equipment of type *mt* $K_{wyd}(mt)$

$$K_{wyd}(mt) = E_{UT}(mt) \cdot \gamma_{wyd}(mt), \tag{21}$$

where $\gamma_{wyd}(mt)$ is the inspection and repair factor depending on the type of equipment and the intensity of its operation.

Equipment operations in the intermodal terminal are directly related to the labour costs of employees serving this equipment. These costs will depend on the scope of their work. Hence, workers are divided into different categories of work *f*, which should be taken into account when calculating annual labour costs.

Human labour costs, in addition to equipment operation costs, are the basic factor that should be estimated and varied depending on the used technology and work organization. Hence, for the purposes of research, the set of types of different categories of human work may take the following form:

$$\boldsymbol{F} = \{1, \ldots, f, \ldots, F\},$$

where F is the set $\boldsymbol{F}$ cardinality.

These costs at the intermodal terminal design stage are calculated from the below formula:

$$K_r^R = \sum_{f \in \boldsymbol{F}} K_r^R(f) \text{ [PLN/year]}, \tag{22}$$

while:

$$K^R(f) = k(f) \cdot g(f) \cdot n(f), \tag{23}$$

and

$$k(f) = k_g(f) \cdot \gamma_{kz} \cdot \frac{1}{\beta_t(f)}, \tag{24}$$

where:
$k(f)$ – working cost of an employee of the *f*-th work category [PLN/h],
$g(f)$ – annual real number of working hours of an employee of the *f*-th work category [h],
$n(f)$ – number of employees of the *f*-th work category,
γ_{kz} – the workplace cost factor, understood as the employer cost incurred in creating the workplace (1.2-1.3),
$k_g(f)$ – gross hourly wage rate for the employee of the *f*-th work category [PLNh],
$\beta_t(f)$ – utilization degree of working time of the employee of the *f*-th work category.

6. Case study

The aim of the calculation example is to calculate the reach-stacker operating costs as well as its operator's labour costs. The organizational, technical, and cost characteristics of the reach-stacker are presented in Tab. 1. Cost and organizational parameters of the operator's work are presented in Tab. 2

The presented calculations should be treated only as examples, showing the principles of their implementation.

Tab. 1. Loading equipment maintenance costs

Parameter	Cost
Initial equipment value	2,200,000 PLN
Final equipment value	700,000 PLN
Equipment lifetime	7 years
Annual depreciation cost factor	0.1
Sum of the annual depreciation cost	214,286 PLN
Credit time (without own capital)	5 years
Average annual interest rate factor on own capital	0.03
Annual cost of the interest rate of own capital	66,000 PLN
Cost factor of inspection and repair	0.08
Costs depending on the performance of an equipment	176000 PLN
Annual fuel costs	180,000 PLN
20 L/h, fuel price 4.5 PLN/L	
Sum of annual costs	636,286 PLN
Annual number of working hours	2000
Equipment working cost per hour	318.14 PLN

Tab. 2. Reach stacker operator labour costs

Parameter	Cost
Employee gross salary per month	4,000
Annual real number of working hours	1,690
Workplace cost factor	1.3
Utilization degree of working time	0.8
Gross hourly wage rate	25.56
Gross monthly salary /(22 days, 8 hours per day)	
Hourly labour cost from the employer's point of view	41.53
Annual gross labour costs	70,185.70
Annual labour cost from the employer's point of view	91,241.41

7. Summary

In conclusion, it should be noted that increasing volumes of freight carried by intermodal transport would in the near future imply the need to decide on the construction of new intermodal terminals and optimize the processes in existing ones. The design of the intermodal terminal requires a number of criteria to be considered at the design stage. One of these criteria is the expenditure on the construction of the intermodal terminal and the cost of its operation, which will result from the applied technology and work organization. The technology used in the long term affects the financial ratios achieved by the terminal. The elements of its infrastructure (tracks, roads, buildings) and superstructures (loading equipment) are the major components of the terminal's construction and equipment expenditures. It should be noted here that the most expensive equipment used in intermodal terminals are cranes. In this case, the capacity of the crane is not significantly higher than that of the reach stackers. Therefore, equipping the terminal with cranes will have economic justifications for high terminal turnover and the need to store intermodal units in multiple blocks and layers. Apart from expenditures and costs, an important element in the design of an intermodal terminal is its location in the logistics network. The proximity, as well as the throughput of road and rail infrastructure significantly affects the size of the terminal area. Therefore, a significant number of factors to consider when designing an intermodal terminal require decision-making based on multi-criteria decision support tools.

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