Taylor & Francis
Taylor & Francis Group

TRANSPORT
ISSN 1648-4142 print / ISSN 1648-3480 online
2012 Volume 27(3): 327–334
doi:10.3846/16484142.2012.721133

EVALUATION CRITERIA AND A ROUTE SELECTION SYSTEM FOR TRANSPORTATING OVERSIZE AND HEAVYWEIGHT CARGOES

Artūras Petraška[1], Ramūnas Palšaitis[2]

Dept of Transport Management, Vilnius Gediminas Technical University,
Plytinės g. 27, LT-10105 Vilnius, Lithuania
E-mails: [1]arturas@transvelas.lt (corresponding author); [2]trvadyba@vgtu.lt

Submitted 27 April 2012; accepted 28 May 2012

Abstract. Oversize and heavyweight cargoes are usually transported adopting a multimodal transport approach. Everything depends on the places where the cargoes are produced and used. The route for carrying oversize/heavyweight cargo is usually evaluated and designed on individual basis. Thus, an important point is the development of an 'instrument' for an objective evaluation of the entire route for transporting oversize/heavyweight cargo (OHC).

Keywords: oversize, heavyweight, load, criteria, transportation.

1. Introduction

A transport system has to be adequately adjusted to industrial needs and should correspond to the changing requirements for cargo transportation. The application of a systematic approach to the processes of transporting oversize/heavyweight cargoes (OHC) allow reducing the costs of cargo transportation several times, which in principle changes conditions for the economic development and attractiveness of investment. It also provides an opportunity to effectively carry OHC to multiple economically active points located on the curtain territory.

The selection of OHC transportation routes requires the development of an 'instrument' for an objective evaluation of OHC transportation route segments or the entire route applying a universal evaluation points system.

2. Problem Analysis

Evaluation criteria and a route selection system for the transportation of OHC is also the system of quantitative parameters defining ongoing processes in the logistic chain (Petraška *et al.* 2011; Palšaitis, Petraška 2011; Luskin, Walton 2001). The selection of the best option within the system or the model of transportation components depends on the applied system of parameters for the evaluation of separate processes. The system having certain criteria could be evaluated as 'very good' and at the same time might not comply with the other criteria (Brauers 2008; Ginevičius *et al.* 2008; Dėjus 2011). The diversity of transportation indicators is determined by both, system constraints (infrastructure of separate transport modes, technical requirements, financial and time indicators, etc.), functional system requirements (or parts of the system) and an opportunity to quantitatively define and evaluate these restrictions. Thus, when developing the criteria system, first of all, defining the criteria and components of evaluation is a crucial point. The second step is to describe requirements imposed upon the functional system. The third step is a quantitative evaluation of the identified indicators (Kutz 2003). Besides, determining the interface between the indicators is also necessary.

The system for selecting and evaluating OHC transportation routes consists of 16 criteria and relevant sub-criteria creating the possibility of evaluating OHC transportation processes and selecting the most suitable mode of transportation. The system also provides a possibility of comparing transportation processes, routes or route segments.

The purpose of the evaluation criteria system (ECS) is to create an 'instrument' suitable for an objective evaluation of route sections or the entire route for OHC transportation by applying a universal system of evaluation points, which provides an opportunity to objectively select the optimal sections of the route, the mode of transport and the means in each case of transporting OHC. The criteria system also provides the possibility of comparing the routes.

Copyright © 2012 Vilnius Gediminas Technical University (VGTU) Press Technika
http://www.tandfonline.com/TRAN

3. Criteria and Their Characteristics

3.1. Constraints Related to Physical Road Characteristics

Two criteria anticipating in this group are related to the road section pavement and the physical quality of the road pavement during the conducted evaluation.

The impact of conditions for the road section pavement on cargo transportation speed:

$$S_{AD} = l_{A1} \cdot k_{AD} + l_{A2} \cdot k_{AZ},$$

where: S_{AD} – transportation time for the OHC aggregate on the route using motor vehicles; l_{A1} – the length of the asphalt paved road, km; l_{A2} – the length of the gravel road, km; k_{AD} – a coefficient: the reciprocal of an average cargo transportation speed on the asphalt paved road; k_{AZ} – a coefficient: the reciprocal of an average cargo transportation speed on the gravel road.

As example the numerical value of coefficients k_{AD} and k_{AZ} could be calculated according to formula:

$$k_{ij} = \frac{1}{v_{aver}},$$

where: k_{ij} – a numerical value evaluating the criteria of the road pavement in transport mode i on road segment j; v_{aver} – the average speed of transporting OHC by the transport mode under analysis; n – number of segments with different sort of pavement.

In case of inland waterways transport, this criterion has two marginal constraints: the criterion is met or a route is inappropriate:

$$S_{VD} = x_{VD1} \cdot k_{VD1} + x_{VD2} \cdot k_{VD2},$$

where: S_{VD} – transportation time for the OHC aggregate on the route using inland waterways transport; x_{VD1} – the aggregate length of waterway sections where the speed of water transport is unlimited; x_{VD2} – the aggregate length of waterway sections where the speed of water transport is limited and is lower than the maximal speed provided by the technical possibilities of a vehicle; k_{VD1} – a coefficient the reciprocal of a maximal speed value of water transport provided by the technical possibilities of a vehicle; k_{VD2} – a coefficient the reciprocal of a limited speed value in the waterway section.

In case of carrying OHC by railway transport, aggregate route management time depends on speed constraints on railway transport in the territory under analysis:

$$S_{GD} = x_{GD1} \cdot k_{GD1} + x_{GD2} \cdot k_{GD2} + x_{GD3} \cdot k_{GD3},$$

where: S_{GD} – aggregate time for OHC transportation on the railway route; x_{GD1} – the length of the road section between stations; x_{GD2} – the length of the road section at the station; x_{GD3} – the length (km) of the reduced speed section; k_{GD1}, k_{GD2}, k_{GD3} – the coefficients indicating the loss of time due to speed limitations in the above and in restricted speed sections.

Physical quality of the road pavement during evaluation:

This criterion allows evaluating the suitability of the road pavement for cargo transportation and expressing the need for relevant actions to ensure appropriate road quality.

The aggregate value of road costs is evaluated:

$$F_{AQ} = x_{AF1} \cdot k_{AF1} + x_{AF2} \cdot k_{AF2} + x_{AF3} \cdot k_{AF3},$$

where: F_{AQ} – an aggregate value of financial costs necessary to improve the route for transporting OHC using road transport; x_{AF1}, x_{AF2}, x_{AF3} – the number of sections requiring minor improvements, capital works or new road construction in the segments of 100m; k_{AF1}, k_{AF2}, k_{AF3} – the coefficients expressing the average costs of minor improvements, capital works and construction of a new road segment on the motor road.

The construction of a new local road or urban street:

For evaluating these criteria, it is expedient to take an equivalent distance of 100 meters. A numerical value of the criteria could be estimated as:

$$K_{nk} = (l_k \cdot k) + (t_s \cdot d),$$

where: K_{nk} – the numerical value of the criterion 'construction of a new road'; l_k –the length of the new road; k – construction price per one road kilometre; t_s – road/object construction time; d – the amount of possible financial costs (loss).

If there are no constraints, the speed of OHC transportation by inland waterway transport is constant. If the problem of waterway depth is encountered in a short inland waterway section, it could be deepened:

$$F_{VQ} = x_{VF1} \cdot k_{VF1},$$

where: F_{VQ} – the aggregate value of financial costs necessary to improve the route for transporting OHC using inland waterways; x_{VF1} – the number of inland waterway sections that require deepening (calculating the number of 100 m sections); k_{VF1} – the coefficient evaluating the price of deepening one 100 m road section.

In case of railways, this criterion has two marginal values, i.e. quality is acceptable (criterion weight is equal to 0) or cargo cannot be transported:

$$F_{GQ} = x_{GF1} \cdot k_{GF1} + x_{GF2} \cdot k_{GF2},$$

where: F_{GQ} – the aggregate value of financial costs necessary to improve the route for transporting OHC by railways; x_{GF1}, x_{GF2} – the length of the section that needs capital works or constructing a new road; k_{GF1}, k_{GF2} – the coefficients expressing the average costs of capital works or construction of a new track in the railway section.

3.2. Obstacles Related to the Geometry of the Road Section

The best way to qualify this criterion is to apply the concept of the cargo transportation corridor that defines cargo transportation dimensions (height, width and curvature). The aspects of this criterion are analyzed below applying each of the above described dimensions.

Small-radius road curves:

$$F_{AS} = x_{AS1} \cdot k_{AS1} + x_{AS2} \cdot k_{AS2},$$

where: F_{AS} – the aggregate value of financial costs to increase curve radius on the route for transporting OHC using motor transport; x_{AS1}, x_{AS2} – the number of minor improvements or capital works on the road route ensuring the required curve radius; k_{AS1}, k_{AS2} – the coefficients expressing average costs required for executing minor or capital improvements within the radius of the road curve on the route.

In case of inland waterways, minor improvements on the route would mean slight straightening of the waterway radius cleaning the waterway channel or executing section straightening works:

$$F_{VS} = x_{VS1} \cdot k_{VS1} + x_{VS2} \cdot k_{VS2},$$

where: F_{VS} – the aggregate value of financial costs for increasing the curve radius on the route for transporting OHC by inland waterway transport; x_{VS1}, x_{VS2} – the number of minor or capital works on the inland waterway route ensuring the required curve radius; k_{VS1}, k_{VS2} – the coefficients expressing average costs required for implementing minor or capital improvements within the curve radius of the inland waterway on the route.

In case of railway transport, this criterion has two marginal values: curve radius is acceptable and reconstructions are not necessary or are inadequate (i.e. cargo cannot be transported), straightening the radius of the railway curve could be considered only of this route is planned for multiple and long-term transportation of OHC cargoes:

$$F_{GS} = x_{GS1} \cdot k_{GS1} + x_{GS2} \cdot k_{GS2},$$

where: F_{GS} – the radius aggregate value of financial costs to increase the curvature radius for transporting OHC by railways; x_{GS1}, x_{GS2} – the radius number of minor or capital improvements in the railway track on the route to ensure the required curve radius; k_{AS1}, k_{AS2} – the coefficients expressing average costs to execute minor or capital improvements within the curve radius of the railway track on the route.

A transportation corridor on the road section is too narrow:

The cargo transportation corridor on the road section is too narrow:

$$F_{AKS} = x_{AKS1} \cdot k_{AKS1} + x_{AKS2} \cdot k_{AKS2} + x_{AKS3} \cdot k_{AKS3},$$

where: F_{AKS} – the aggregate value of financial costs to increase the width of the corridor for transporting OHC by road transport; x_{AKS1}, x_{AKS2}, x_{AKS3} – the number of minor improvements, capital works or impassable sections on the motor road ensuring the required width of the corridor; k_{AKS1}, k_{AKS2} – the coefficients expressing average costs for executing minor or capital works on widening the motor road corridor on the route; k_{AKS3} – the coefficient equals infinity.

In case of the inland waterway route, if the width of the corridor does not comply with cargo transportation requirements, it is necessary to select another transportation alternative (option):

$$F_{VKS} = x_{VKS1} \cdot k_{VKS1} + x_{VKS2} \cdot k_{VKS2} + x_{VKS3} \cdot k_{VKS3},$$

where: F_{VKS} – the aggregate value of financial costs to increase the width of the OHC carriage corridor for transportation using inland waterway transport; x_{VKS1}, x_{VKS2} – the number of minor or capital works on the inland waterway route ensuring the required width of the transportation corridor; x_{VKS3} – the number of impassable sections on the inland waterway route; k_{VKS1}, k_{VKS2} – the coefficients expressing average costs for executing minor and capital widening works in the inland waterway corridor on the route; k_{VKS3} – the coefficient equals infinity (the route cannot be used).

This criterion in railway transport has two marginal values: the width of the corridor meets the requirements and reorganisations are unnecessary or inadequate, i.e. cargo cannot be transported:

$$F_{GKS} = x_{GKS1} \cdot k_{GKS1} + x_{GKS2} \cdot k_{GKS2} + x_{GKS3} \cdot k_{GKS3},$$

where: F_{GKS} – the aggregate value of financial costs required to increase the width of the corridor for transporting OHC by railways; x_{GKS1}, x_{GKS2} – the number of minor improvements and capital works on the railway route ensuring the required width of the transportation corridor; x_{GKS3} – the number of impassable routes on the railway route; k_{GKS1}, k_{GKS2} – the coefficients expressing average costs for executing minor or capital works on improving the width of the railway corridor; k_{GKS3} – the coefficient equals infinity (another transportation alternative must be found).

A cargo transportation corridor on the road section is too low:

The evaluation of capital works to ensure the required height of the corridor: the criterion provides for evaluating the impact of reorganizing various technological installations along the route of OHC on the selection of the entire route:

$$F_{AKZ} = x_{AKZ1} \cdot k_{AKZ1} + x_{AKZ2} \cdot k_{AKZ2} + x_{AKZ3} \cdot k_{AKZ3},$$

where: F_{AKZ} – the aggregate value of financial costs to increase the height of the corridor for transporting OHC by motor transport; x_{AKZ1}, x_{AKZ2} – the number of minor or capital improvements on the road route ensuring the required height of the transportation corridor; x_{AKZ3} – the number of impassable routes on the road section due to height constraints; k_{AKZ1}, k_{AKZ2} – the coefficients expressing average costs for executing minor or capital improvements on the motor road on the route to ensure the required height of the transportation corridor; k_{AKZ3} – the coefficient equals infinity. In case of a critical place on the road route and due to the height of the transportation corridor that cannot be eliminated, bypassed, reconstructed or otherwise avoided, the possibility of cargo transportation on the above route is not considered.

On the inland waterway route:

$$F_{VKZ} = x_{VKZ1} \cdot k_{VKZ1} + x_{VKZ2} \cdot k_{VKZ2} + x_{VKZ3} \cdot k_{VKZ3},$$

where: F_{VKZ} – the aggregate value of financial costs required to increase the height of the corridor for transporting OHC by inland waterway transport; x_{VKZ1}, x_{VKZ2} – the number of minor or capital works on the inland waterway route by ensuring the required height of the transportation corridor; x_{VKZ3} – the number of impassable sections on the inland waterway route; k_{VKZ1}, k_{VKZ2} – the coefficients expressing average costs required for executing minor or capital improvements in inland waterways on the route to ensure the required height of the transportation corridor; k_{VKZ3} – the coefficient equals infinity. It means that in case of critical height restriction on the inland waterway route that cannot be eliminated within reasonable costs or otherwise avoided, the possibility of cargo transportation on the above route is not considered.

On the railway:

$$F_{GKZ} = x_{GKZ1} \cdot k_{GKZ1} + x_{GKZ2} \cdot k_{GKZ2} + x_{GKZ3} \cdot k_{GKZ3},$$

where: F_{GKZ} – the aggregate value of financial costs required to increase the height of the corridor for transporting OHC by railway transport; x_{GKZ1}, x_{GKZ2} – the number of minor improvements or capital works on the railway route ensuring the required height of the transportation corridor; x_{GKZ3} – the number of impassable sections on the railway route due to height constraints; k_{GKZ1}, k_{GKZ2} – the coefficients expressing average costs for executing minor improvements or capital works on the railway route to ensure the required height of the transportation corridor; k_{GKZ3} – the coefficient equals infinity.

Obstacles related to bridges/dams on the route. Insufficient loading capacity of bridges:

$$F_{AT} = x_{AT1} \cdot k_{AT1} + x_{AT2} \cdot k_{AT2} + x_{AT3} \cdot k_{AT3} + x_{AT4} \cdot k_{AT4},$$

where: F_{AT} – the aggregate value of financial costs required to ensure the terms of transporting OHC via bridges or viaducts on the route, or to determine that such transportation by motor transport is impossible; x_{AT1} – the number of spots on the motor road section where feasible to use a steel ramp to ensure the movement of OHC via bridges and viaducts on the route; x_{AT2} – the number of the newly constructed viaducts on the motor road section; x_{AT3} – the number of new bridges to be constructed on the motor road section; x_{AT4} – the number of impassable sections on the road route; k_{AT1} – the coefficient expressing average costs for installing/dismantling a steel ramp; k_{AT2} – the coefficient expressing average costs for constructing a viaduct on the route; k_{AT3} – the coefficient expressing average costs for building a new bridge on the motor road section; k_{AT4} – the coefficient equals infinity (another transportation alternative must be found).

Cargo transportation by inland waterways:

$$F_{VT} = x_{VT1} \cdot k_{VT1} + x_{VT2} \cdot k_{VT2} + x_{VT3} \cdot k_{VT3},$$

where: F_{VT} – the aggregate value of financial costs required to ensure the terms of transporting OHC by inland waterways or to determine that such transportation is impossible; x_{VT1}, x_{VT2} – the number of works for lock improvement or the installation of new locks and channel segments on inland waterway routes; x_{VT3} – the number of critical points on the route that cannot be eliminated within reasonable costs; k_{VT1}, k_{VT2} – the coefficient expressing average costs for improving dyke locks or construction of new locks; k_{VT3} – the coefficient equals infinity.

Obstacles on the railway route due to a low load capacity of bridges and viaducts:

$$F_{GT} = x_{GT1} \cdot k_{GT1} + x_{GT2} \cdot k_{GT2} + x_{GT3} \cdot k_{GT3},$$

where: x_{GT1} – the number of enforcements required for bridges on the route; x_{GT2} – the number of necessary bridge enforcements on the railway route; x_{GT3} – the number of impassable sections on the railway route; k_{GT1} – the coefficient expressing average costs for installing/dismantling bridge enforcements on the route; k_{GT2} – the coefficient expressing average costs for constructing a new bridge on the route; k_{GT3} – the coefficient equals infinity. It means that in case of a critical spot on the railway route not meeting requirements for transporting OHC that cannot be eliminated, bypassed, reconstructed or otherwise avoided, the possibility of cargo transportation on this route is not considered.

As example, a numerical value of the criterion 'construction of a new bridge' is estimated applying the formula:

$$k_{GT2} = \left(l_T \cdot a_T \cdot k_T\right) + \left(t_T \cdot d\right),$$

where: k_{GT2} – the numerical value of the criterion 'construction of a new bridge'; l_T – the length of the constructed bridge in metres; a_T – the width of the constructed bridge in metres; k_T – the cost of bridge construction per square metre; t_T – bridge/object construction time; d – the amount of possible financial costs (loss).

3.3. Construction of a Viaduct

The weight of this criterion is estimated by evaluating time for designing and constructing a viaduct and the value of constructing a bypass road:

$$K_{pr} = \left(l_k \cdot k\right) + \left(t_s \cdot d\right) + \left(l_P \cdot a_P \cdot k_P\right) + \left(t_P \cdot d\right),$$

where: K_{pr} – the numerical value of the criterion 'viaduct construction'; l_k – the length of a new road in kilometres; k – the price of construction of one road kilometre; t_s – time for constructing a road circuit ; d – the amount of possible financial costs (loss); l_P – the length of the constructed viaduct in metres; a_P – the width of the constructed viaduct in metres; k_P – the cost per square metre of the constructed viaduct; t_P – the time of buiding new viaduct.

In case of a possibility of using a steel ramp, the numerical value of the criterion can be estimated as follows:

$$K_{ramp} = \left(t_R \cdot d\right) + K_{nk},$$

where: K_{ramp} – the numerical value of the criterion 'required steel ramp'; t_R – time for ramp installation; d – the amount of possible financial costs (loss); K_{nk} – the construction of a new local road.

Considering road transport, the numerical value of coefficient K_{ramp} depends on ramp procurement/delivery time t_1 and construction/installation time t_{2ramp}:

$$t_R = t_1 + t_{2ramp},$$

where: t_R – time for installing an aggregate ramp; t_1 – ramp procurement/delivery time; t_{2ramp} – ramp assembly/dismantling time.

3.4. The Weight of Transported Cargo

This criterion is important for evaluating the selected modes of cargo transportation, yet it has the least impact on inland waterway transport:

$$k_{sv} \in \left(t_{kr}, k_y\right),$$

where: k_{sv} – the numerical value of dependence on the criterion for cargo weight; t_{kr} – time for delivering cargo installations to the territory under analysis; k_y – the price of leased installations.

$$k_{sv} = \left(t_{kr} \cdot d\right) + k_y,$$

where: d – the amount of possible financial costs (loss).

3.5. The Total Length of the Route

This criterion falls into the category of consistently changing factors:

$$F_{\Sigma L} = \sum l_i \cdot c_{ikm},$$

where: $F_{\Sigma L}$ – the aggregate price of transporting OHC by multimodal transport; l_i – the distance of transporting OHC in kilometres in transportation mode *i*; c_{ikm} – the cost of 1 transportation km of oversize/heavyweight in transport mode *i*.

The weight of the criterion evaluating the total length of the route is estimated taking into account time for OHC transportation and social costs:

$$k_{lenght} = t_K \cdot d,$$

where: k_{lenght} – length numerical value of the total length of the route; t_K – forecasted time for cargo transportation; d – the amount of possible financial costs (loss).

3.6. The Need for the Establishment of Reloading Facilities

In case of transporting OHC by motor transport, the aggregate value of the costs required for installing a cargo reloading facility is estimated:

$$F_{AP} = x_{AP1} \cdot k_{AP1},$$

where: F_{AP} – costs for the installation of reloading a facility on the road route; x_{AP1} – the number of reloading facilities to be installed for reloading OHC to another mode of transport on the road route; k_{AP1} – the coefficient expressing average costs for the installation of a reloading facility for reloading OHC to another mode of transport on the road route.

The transportation of OHC by inland waterways:

$$F_{VP} = x_{VP1} \cdot k_{VP1},$$

where: F_{VP} – the costs of the installation of a reloading facility on the inland waterway route; x_{VP1} – the number of reloading facilities to be installed for reloading OHC on the inland waterway route; k_{VP1} – the coefficient expressing average costs for the installation of a reloading facility for OHC on the inland waterway route.

The costs of installing a reloading facility on the railway route are estimated:

$$F_{GP} = x_{GP1} \cdot k_{GP1},$$

where: F_{GP} – the costs of installing a reloading facility on the railway route; x_{GP1} – the number of reloading facilities to be installed for OHC on the railway route; k_{GP1} – the coefficient expressing the average costs of installing a reloading facility for reloading OHC on the railway route.

The criteria evaluating the need for the construction of reloading and cargo storage facilities are as follows:

$$K_{reloading} = t_{krv} \cdot d + k_{krv},$$

where: $K_{reloading}$ – the numerical value of the criterion 'the need for a reloading facility'; t_{krv} – time for the installation of a reloading facility; k_{krv} – price for the installation of a reloading facility; d – the amount of possible financial costs (loss).

3.7. The Need for the Construction of Cargo Storage Facilities

The costs of the construction of storage facilities on the road route are estimated:

$$F_{AY} = x_{AY1} \cdot k_{AY1},$$

where: F_{AY} – the costs of constructing a storage facility on the road route; x_{AY1} – the number of storage facilities to be constructed for storing OHC on the road route; k_{AY1} – the coefficient expressing the average costs of constructing a storage facility for OHC on the road route.

The costs of constructing a storage facility for transporting OHC by inland waterways are estimated:

$$F_{VY} = x_{VY1} \cdot k_{VYZ1},$$

where: F_{VY} – the costs of a storage facility on the inland waterway route; x_{VY1} – the number of storage facilities for OHC in inland waterway transport; k_{VY1} – the coefficient of the average costs of constructing a storage facility for OHC on the inland waterway route.

The costs of constructing a storage facility on the railway route are estimated:

$$F_{GY} = x_{GY1} \cdot k_{GY1},$$

where: F_{GY} – the costs of constructing a storage facility on the railway route; x_{GY1} – the number of storage facilities to be constructed for OHC on the railway route; k_{GY1} – the coefficient expressing the average costs of constructing a storage facility for OHC on the railway route.

The need for a cargo storage facility: the facility is necessary at the cargo delivery point or/and in certain spots of the route:

$$K_{storage} = t_{sa} \cdot d + k_{sa},$$

where: $K_{storage}$ – the numerical value of the criterion 'the need for a storage facility'; t_{sa} – time for constructing a storage facility; k_{sa} – price for constructing a storage facility; d – the amount of possible financial costs (loss).

3.8. Obstacles Due to Juridical (Including Environmental) Requirements

$$F_{Jij} = \sum x_{Jij} \cdot k_{Jij},$$

where: F_{Jij} – aggregate costs eliminating obstacles due to juridical restrictions in transportation mode i on route segment j; x_{Jij} – the number of protected territories, permits for installing a reloading facility, bypassed cities/settlements on the route of a relevant mode; k_{Jij} – loss compensation coefficients in transportation mode i on route segment j (coefficients related to social loss, permits for constructing a reloading facility and temporary storage facility).

3.9. Time Loss Due to the Intensity of Conventional Transport on the Road Route Under Analysis

$$S_{Iij} = \sum x_{Iij} \cdot k_{Iij},$$

where: S_{Iij} – aggregate additional time costs of transporting OHC in transport mode i via route segment j; x_{Iij} – the length of the road section of different intensity (low, average, high) on the route in transport mode i on route segment j; k_{Iij} – the coefficient determining the speed of a freight train in the track section of different traffic intensity.

3.10. The Impact of Seasonality on Cargo Transportation

$$K_{SE} = 0.5 \cdot x_S^2,$$

where: K_{SE} – the numerical value of the criterion 'seasonality'; x_s – a period: the number of months when OHC cannot be transported. This dimension might acquire the values from 0 to 12 (when x_S value is 12, this alternative is not further considered).

3.11. Route Flexibility in Case of Unforeseen Obstacles

The possibility of changing a cargo transportation route is analysed evaluating the risk of transporting specific cargo via a specific route.

3.12. Current Experience of Transporting OHC

This criterion is used for evaluating the experience of each transport mode carrying OHC cargo. It is especially important to evaluate the existing experience of the carriers dealing with OHC in the above sphere:

$$E_{ij} \in \begin{cases} N, N = \left[0;3\right]; \\ M, M = \left[3;20\right]; \\ D, D = \left[20,...,n\right], \end{cases}$$

where: E_{ij} – the coefficient evaluating the current experience of carrying OHC in transport mode i on road segment j; N – no experience of carrying OHC; M – little experience of carrying OHC; D – extensive experience of carrying OHC.

Experience is suposed to be high if carrier has implemented 20 or more OHC transportations, medium experience is suposed if carrier has implemented between 3 and 20 OHC transportations, experience is suposed to be low if carrier has implemented less then 3 OHC transportations.

3.13. Criteria Related to the Realization of Transporting OHC

Cargo tax 'burden':

The calculation of a provisional price of a permit for transporting OHC:

$$F_{tax} = \left(l_1 - l_0\right) \cdot k_{x1} + \left(w_1 - w_0\right) \cdot k_{x2} + \left(h_1 - h_0\right) \cdot k_{x3},$$

where: F_{tax} – the sum of the tax on the exceeded permitted parameters of a vehicle loaded with cargo; l_1 – the length of a vehicle loaded with cargo; l_0 – the permitted length of a vehicle;k_{x1} – tax rate of the exceeded length of a vehicle; w_1 – the width of a vehicle loaded with cargo; w_0 – the permitted width of a vehicle; k_{x2} – tax rate of the exceeded width of a vehicle; h_1 – the height of a vehicle loaded with cargo; h_0 – the permitted height of a vehicle; k_{x3} – tax rate of the exceeded height of a vehicle.

Availability of the vehicles required for cargo transportation:

$$F_{HFP} \in \begin{cases} P_H; \\ P_F; \\ P_P, \end{cases}$$

where: F_{HFP} – aggregate costs of delivering OHC transportation vehicles; P_H – the costs incurred when OHC transportation vehicles are available in the territory of transportation; P_F – the costs incurred when an OHC transportation vehicle must be delivered from another country; P_P – the costs incurred when a new vehicle for transporting OHC must be produced.

4. The System for Criteria Applied for Route Evaluation

It would be expedient to establish a system for ensuring an objective evaluation of OHC transportation processes comparing different transport modes, route segments and transportation/cargo reload technologies.

The process of designing the route for transporting OHC is presented in Figure. The process begins from the identification of the initial and final route points.

The preparation of the route for transporting OHC includes the anticipation of the route in the geographical territory depending on geographical circumstances. All transport modes are evaluated, including roads, railways, inland waterways or water reservoirs that could be used as waterways.

For selecting a route, a solution is a minimum value of an objective function.

The system connecting the criteria related to time dimension for evaluating the route of road transport:

$$Z_{\min}\left(S\right) = \begin{cases} S_{AD} = l_{A1} \cdot k_{AD} + l_{A2} \cdot k_{AZ}; \\ S_{AI} = x_{AI1} \cdot k_{AI1} + x_{AI2} \cdot k_{AI2} + x_{AI3} \cdot k_{AI3}; \\ K_{SE} = 0.5 \cdot x_s^2. \end{cases}$$

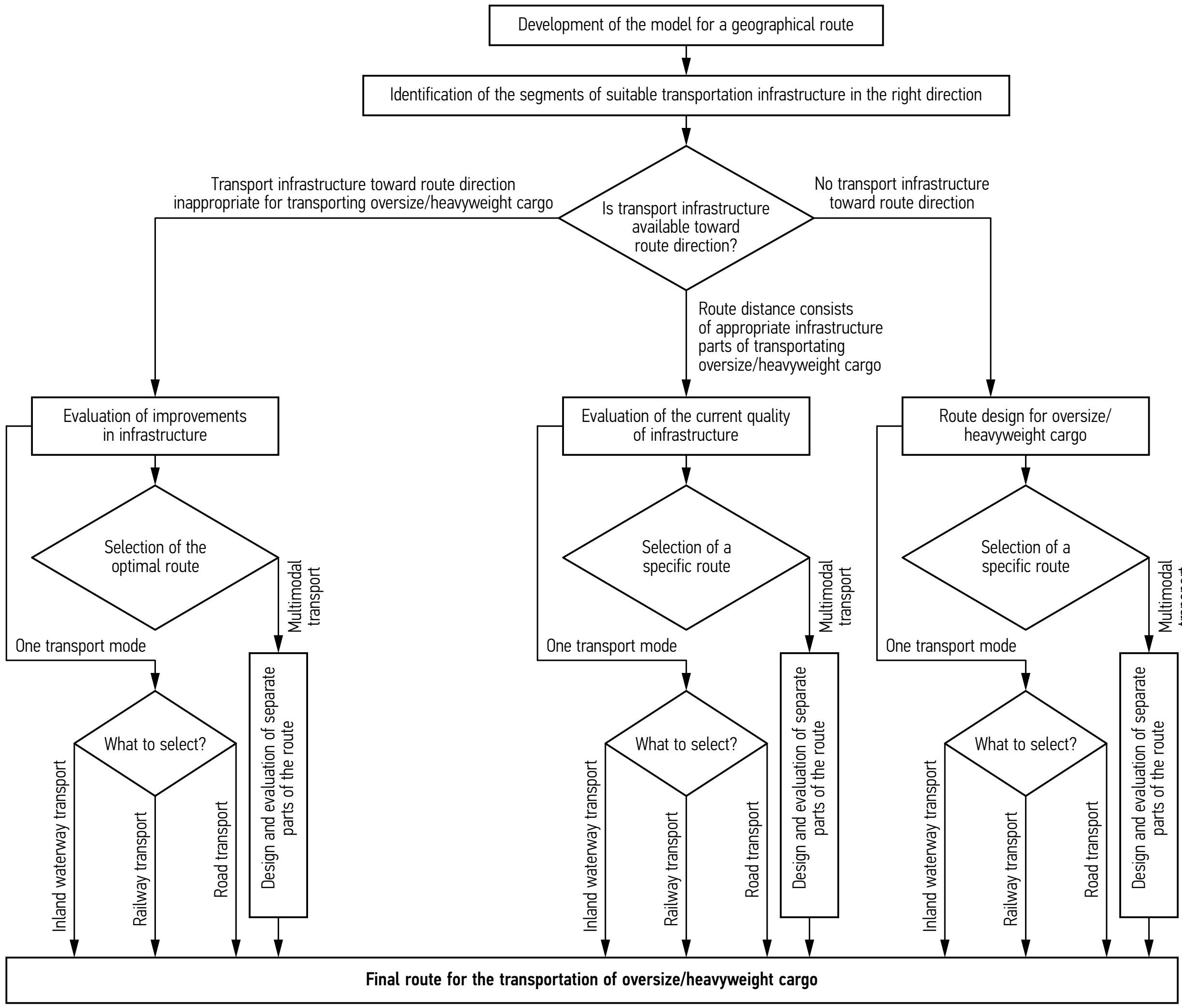

Fig. The algorithm for selecting a route for transporting oversize heavyweight cargo

The system connecting the criteria related to financial dimension for evaluating the route of road transport:

$$Z_{\min}(F)=\begin{cases} F_{AQ}=x_{AF1}\cdot k_{AF1}+x_{AF2}\cdot k_{AF2}+x_{AF3}\cdot k_{AF3};\\ F_{AS}=x_{AS1}\cdot k_{AS1}+x_{AS2}\cdot k_{AS2};\\ F_{AKS}=x_{AKS1}\cdot k_{AKS1}+x_{AKS2}\cdot k_{AKS2}+x_{AKS3}\cdot k_{AKS3};\\ F_{AKZ}=x_{AKZ1}\cdot k_{AKZ1}+x_{AKZ2}\cdot k_{AKZ2}+x_{AKZ3}\cdot k_{AKZ3};\\ F_{AT}=x_{AT1}\cdot k_{AT1}+x_{AT2}\cdot k_{AT2}+x_{AT3}\cdot k_{AT3}+x_{AT4}\cdot k_{AT4};\\ F_{AP}=x_{AP1}\cdot k_{AP1};\\ F_{AY}=x_{AY1}\cdot k_{AY1};\\ F_{AJ}=x_{AJ1}\cdot k_{AJ1}+x_{AJ2}\cdot k_{AJ2}+x_{AJ3}\cdot k_{AJ3}+x_{AJ4}\cdot k_{AJ4};\\ F_{tax}=\left(l_1-l_0\right)\cdot k_{x1}+\left(w_1-w_0\right)\cdot k_{x2}+\left(h_1-h_0\right)\cdot k_{x3};\\ R=\dfrac{\sum a}{e^{\lambda}\sum k_{se}}\sum C_i. \end{cases}$$

In all applied transportation modes risk should be evaluated. The system defining this criteria is described above, where: R means value of risk; a – intensiveness of traffic in diferent transportation modes; e – basics of natural logarithm; Σk_{se} – total impact of variuos safety elements to the probability of accident; ΣC_i – consequenses of accident.

The system connecting the criteria related to time dimension for evaluating the route of inland waterway:

$$Z_{\min}(S)=\begin{cases} S_{VD}=x_{VD1}\cdot k_{VD1}+x_{VD2}\cdot k_{VD2};\\ S_{VI}=x_{VI1}\cdot k_{VI1}+x_{VI2}\cdot k_{VI2}+x_{VI3}\cdot k_{VI3};\\ K_{SE}=0.5\cdot x_s^2. \end{cases}$$

The system connecting the criteria related to financial dimension for evaluating the route of inland waterway:

$$Z_{\min}(F)=\begin{cases} F_{VQ}=x_{VF1}\cdot k_{VF1};\\ F_{VS}=x_{VS1}\cdot k_{VS1}+x_{VS2}\cdot k_{VS2};\\ F_{VKS}=x_{VKS1}\cdot k_{VKS1}+x_{VKS2}\cdot k_{VKS2}+x_{VKS3}\cdot k_{VKS3};\\ F_{VKZ}=x_{VKZ1}\cdot k_{VKZ1}+x_{VKZ2}\cdot k_{VKZ2}+x_{VKZ3}\cdot k_{VKZ3};\\ F_{VT}=x_{VT1}\cdot k_{VT1}+x_{VT2}\cdot k_{VT2}+x_{VT3}\cdot k_{VT3};\\ F_{VP}=x_{VP1}\cdot k_{VP1};\\ F_{VY}=x_{VY1}\cdot k_{VY1};\\ F_{VJ}=x_{VJ1}\cdot k_{VJ1}+x_{VJ2}\cdot k_{VJ2}+x_{VJ3}\cdot k_{VJ3}+x_{VJ4}\cdot k_{VJ4};\\ R=\dfrac{\sum a}{e^{\lambda}\sum k_{se}}\sum C_i. \end{cases}$$

The system connecting the criteria related to time dimension for evaluating the route of railway transport:

$$Z_{\min}(S)=\begin{cases}S_{GD}=x_{GD1}\cdot k_{GD1}+x_{GD2}\cdot k_{GD2}+x_{GD3}\cdot k_{GD3};\\ S_{GI}=x_{GI1}\cdot k_{GI1}+x_{GI2}\cdot k_{GI2}+x_{GI3}\cdot k_{GI3};\\ K_{SE}=0.5\cdot x_s^2.\end{cases}$$

The system connecting the criteria related to financial dimension for evaluating the route of railway transport:

$$Z_{\min}(F)=\begin{cases}F_{GQ}=x_{GF1}\cdot k_{GF1}+x_{GF2}\cdot k_{GF2};\\ F_{GS}=x_{GS1}\cdot k_{GS1}+x_{GS2}\cdot k_{GS2};\\ F_{GKS}=x_{GKS1}\cdot k_{GKS1}+x_{GKS2}\cdot k_{GKS2}+x_{GKS3}\cdot k_{GKS3};\\ F_{GKZ}=x_{GKZ1}\cdot k_{GKZ1}+x_{GKZ2}\cdot k_{GKZ2}+x_{GKZ3}\cdot k_{GKZ3};\\ F_{GT}=x_{GT1}\cdot k_{GT1}+x_{GT2}\cdot k_{GT2}+x_{GT3}\cdot k_{GT3};\\ F_{GP}=x_{GP1}\cdot k_{GP1};\\ F_{GY}=x_{GY1}\cdot k_{GY1};\\ F_{GJ}=x_{GJ1}\cdot k_{GJ1}+x_{GJ2}\cdot k_{GJ2}+x_{GJ3}\cdot k_{GJ3}+x_{GJ4}\cdot k_{GJ4};\\ F_{tax}=(l_1-l_0)\cdot k_{x1}+(w_1-w_0)\cdot k_{x2}+(h_1-h_0)\cdot k_{x3};\\ R=\dfrac{\sum a}{e^{\lambda}\sum k_{se}}\sum C_i.\end{cases}$$

While evaluating separate parts of the route, the above presented mathematical model for assessing the route of OHC is used. The model allows comparing objectively separate segments of the route and the entire chain. The criteria are divided into two groups in each mode of transport within the system. The first group is designed for evaluating the impact of cargo transportation route parameters; the objective of the second group is to evaluate the impact of cargo on the transportation process.

5. Conclusions

1. A set of 16 criteria, including separate sub-criteria has been established. The set defines OHC transportation processes and evaluates route parameters, transportation modes and transport means. This provides a possibility of evaluating all OHC transportation processes in the common system by means of comparison.
2. Establishing a system of criteria that provides a possibility of an objective evaluation of OHC transportation processes by comparing separate modes of transport, route segments, transportation and cargo reload technologies, makes it practically applicable in any territory.
3. The system provides a possibility of an objective comparison of OHC transportation alternatives using various modes of transport considering two aspects: time and costs related to technical works and consideration of juridical issues. The system also evaluates the influence of the social aspects and risks of cargo transportation.
4. The system is appropriate not only for evaluating the current OHC transportation opportunities in the territory, but also for developing long-term routes for cargo transportation according to economic development criteria.

References

Brauers, W. K. M. 2008. Multi-objective decision making by reference point theory for a wellbeing economy, *Operational Research* 8(1): 89–104. http://dx.doi.org/10.1007/s12351-008-0013-7

Dėjus, T. 2011. Safety of technological projects using multi-criteria decision making methods, *Journal of Civil Engineering and Management* 14(4): 177–183. http://dx.doi.org/10.3846/13923730.2011.576809

Ginevičius, R.; Podvezko, V.; Raslanas, S. 2008. Evaluating the alternative solutions of wall insulation by multicriteria methods, *Journal of Civil Engineering and Management* 14(4): 217–226. http://dx.doi.org/10.3846/1392-3730.2008.14.20

Kutz, M. 2003. *Handbook of Transportation Engineering*. 1st edition. McGraw-Hill Professional. 1000 p.

Luskin, D. M.; Walton, C. M. 2001. *Effects of Truck Size and Weights on Highway Infrastructure and Operations: a Synthesis Report*. Research Report 0-2122-1. The University of Texas at Austin. 72 p. http://www4.cc.utexas.edu/research/ctr/pdf_reports/2122_1.pdf

Palšaitis, R.; Petraška, A. 2011. Heavy goods transportation risk management, in *Proceedings of the 11th International Conference 'Reliability and Statistics in Transportation and Communication' (RelStat'11)*. 19–22 October 2011, Riga, Latvia, 181–185.

Petraška, A.; Palšaitis, R.; Batarlienė, N.; Bazaras, D. 2011. Evaluation criteria system of the routes for super heavy and oversized cargo, in *Transport Means – 2011: Proceedings of the 15th International Conference*. 20–21 October 2011, Kaunas, Lithuania, 236–239.