

THE POSSIBILITY OF TRANSPORTATION OF OVERSIZED ITEMS

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Abstract

The Czech Republic has been historically a major producer of engineering products that includes unique products, although their size usually exceeds standard dimensions or weight. These types of products have high value added and are important for export. In the heavy machinery it is e.g. mining and metallurgical equipment, and other components for installation of turn-key investment units. So called light engineering also produces machinery and equipment, which can be categorized as oversized items. Locations with manufacturing plants that produce products for the chemical, energy and also the automotive industry are located all over the Czech Republic. Important areas of production are especially the Ostrava Region, the Pilsen Region, The Central Bohemia Region, the Usti Region and also the South Moravian Region. The transportation of these oversized items is from logistical, transportation and organizational point of view such a complicated process into where not only a manufacturer and a carrier enter. Also relevant government authorities and other organizations are having high influence. Although the transportation of oversized items is only a small part of the total volume of traffic to and from the Czech Republic, it is a very important part, specifically for export. It is necessary to pay a special attention to this type of transportation also in terms of possibility of using different transportation modes.

Keywords: Oversized item, waterways transport, air transport

1. INTRODUCTION

The transport of oversized items is a specific problem. Even here, selection factors which are identical to those applicable to other goods, i.e. price, reliability, constant characteristics of the goods during transport, transport time and safety, etc., exist. Further, it is necessary for each individual item to also assess its flexibility, usual frequency of operation, universality and sensitivity to climatic conditions.

However, other factors come into play during transport of oversized items, i.e. the dimensions and weight of the transported item. These specific factors may result in the exclusion of some of the transport modes with regard to the technical parameters (load capacity, width of transport route, clearance height and organisational problems).

Currently, there are products made in the Czech Republic that are characterised particularly by large weight and dimensions; these are large investment units, mining and metallurgical equipment, textile machines, machining tools, technological equipment for the textile industry, etc. It is not always possible to only use one type of transport for the entire transport route. It is therefore important to create a transport model for oversized items within which a combination of transport modes shall be accepted, and thus achieve higher transport efficiency, and consequently also a higher opportunity for domestic manufacturers to export these products.

Although the share of this type of cargo is very small in terms of the total transport volume of exports and imports in the conditions of the Czech Republic as these types of products have very high added value. Exports exceed imports. Waterway transport is mainly used for exports; however, in some isolated cases, upon assessment of the required criteria, it is highly advantageous to also use air transport.

2. TRANSPORT OF OVERSIZED ITEMS FROM AND TO THE CZECH REPUBLIC

The engineering industry substantially impacts the economic significance of the individual areas, it logically also links with the metallurgical, chemical, energy, and automotive industry, distributed all over the Czech Republic. The engineering industry substantially impacts the economic significance of the individual areas. The heavy engineering industry is mainly concentrated near iron works. [10] The important branches are transport engineering, production of machinery and equipment for industry, electrical engineering and electronics. It concerns products with a high added value. Transport of oversized items has a 0.1 % share of total exports (all modes). [8] The financial share is much higher. For exports to the USA, the transport of oversized items is a fundamental area.

Table 1 Total export and import CZ - USA (mil. USD)

CZ - USA	2011	2012	2013	2014	2015
Export	3 344.1	3 930.6	3 922.9	4 344.8	4 462.2
Import	1 684.7	1 832.3	1 943.3	2 302.4	1 978.5

Source: <https://www.census.gov/foreign-trade>

3. TRANSPORT OF OVERSIZED ITEMS

When preparing the transport of oversized items, i.e. after identification of an item as oversized, it is necessary to analyse the possible selection of the transport mode, respectively, combination of transport modes. This analysis must not only contain the technical parameters of the means of transport, but a no less important component is also the detailed analysis of the transport route. An oversized item cannot be transported using ordinary means of transport because it exceeds the set parameters in terms of length, width, height and weight. The division is - **heavy** (they exceed the maximum permissible weight) and **oversized** (they exceed the maximum permissible dimensions).

When using the road, i.e. the width, load capacity and height of the road bridge clearance heights, radii of the bends, width and load capacity of bridges, width and height of underpasses, width and height of tunnels, width and height of limiting technical equipment (e.g. toll gates), longitudinal bank of the road, permissible speed limit. When using railway transport, the decisive parameters are corridor width, load capacity, bridge clearance height, radii of the bends, bridge load capacity, width and height of the tunnels, width and height of the technical equipment on the railway line, permissible speed limit and longitudinal bank of the railway line. No significant technical limitations exist for inland waterway transport in terms of the width and height of the corridor required for transport, and for this reason, it is normally used to transport oversized items if it is not possible to use the above-stated transport modes.

It is further necessary, in the event of using marine transport, to assess the parameters of the handling equipment at the selected port and availability in terms of time.

In some cases it is possible to use air transport for transport of oversized items, which has a higher significance as compared to the other transport modes in terms of delivery speed and reliability.



Figure 1 Schema of logistic chain - combined transport of oversized items
Source: Authors

3.1. Inland waterway transport

The most important watercourse in the Czech Republic in terms of cargo transport is the Elbe waterway and part of the Vltava waterway from the confluence of the Elbe and Vltava to Prague. It is a transport connection to the sea ports of Hamburg, Bremerhaven and Rotterdam and also the network of European inland waterways. It is optimal to combine waterway transport with other modes of transport particularly for the reason that the manufacturing enterprises and industrial centres are usually not located near the waterways. From this viewpoint, the Ústí Region, but also the Central-Bohemian Region and Prague have the best locations; in future, this will also include the Pardubice Region after the realisation of the Přelouč II Lock.

Flow of oversized cargo: Mělník - Hamburg, Antwerpen, Rotterdam, Bremenhaven; Lovosice - Hamburg, Antwerpen, Rotterdam; Ústí nad Labem - Hamburg, Antwerpen.

From the total volume of exports in inland waterway transport, the transport of oversized items has a share of 48 %, while imports amount to approximately 10% of exports.

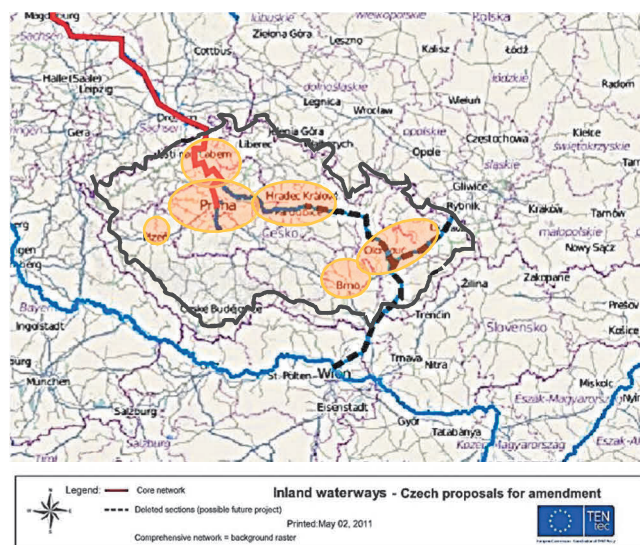


Figure 2 Localities with the biggest production for inland water transport
Source: Authors with facts from ŘVC ČR

It is necessary to transport the oversized item by road or railway to the ports on the waterway. The ports of Mělník, Lovosice, Děčín - Rozbělesy and Děčín fulfil the requirements for connection to waterway, railway and road transport.

By location of the logistics centre near the ports, it is also possible to ensure a long-term increase in the performance of railway transport, which is currently not an important alternative to road transport due to its low flexibility at short distances.

In some cases, however, an oversized item cannot be transported to a port by road or railway. It is then necessary to disassemble it into individual components and re-assemble it at the port.

During selection of a suitable port, it is necessary to evaluate the following influences:

- accessibility - fulfilment of the parameters for connection to the railway and road networks,
- existence of a trans-shipment facility with the required parameters,
- a reinforced quay front and handling area,
- a skinned surface / hall for eventual assembly,
- storage facilities,

- credible forecast of weather conditions - in the case of the Elbe waterway, this concerns the navigation depth,
- costs of connecting transport to / from the port,
- costs of trans-shipment of the oversized item at the port,
- costs of waterway transport from the port.

The technical parameters for transport of oversized items using the inland waterway are as follows. On the Elbe waterway, it is possible to operate boats with maximum dimensions of 135 m length and 11.4 m width with a maximum cargo weight of 1,200 t.

3.2. Railway transport

Transport of an oversized item by railway is strictly limited mainly by the passage profile, i.e. the width and height of the transported item; an important factor is also the permitted axle pressure. In railway terminology, the oversized item is designated as extraordinary freight - it may be accepted for transport only subject to special technical or operating terms and conditions between all the carriers involved in the transport.

Extraordinary freight categories:

- consignments that exceed the load bed dimensions - the dimensions exceed the size of the bed of the given railway set,
- consignments with extraordinary weight (more than 25 t),
- consignments of extraordinary length, which exceed a length of 3.5 to 12 m, [12]
- other consignments.

Table 2 Transport of extraordinary consignments in 2015

	Total export and import (thousands t)	Extraordinary freight (thousands t)	%
ČD Cargo	58 102	232.4	0.4
DB Schenker	-----	-----	< 5

Source: Authors

Note: This primarily concerns export and transport to the ports of Lovosice, Ústí nad Labem, and onwards via the waterway.

3.3. Road transport



Figure 3 Transport of oversized items, road R 10, 14.9.2011. Photo: H. Bínová

In road transport in the Czech Republic, an oversized item [14], which exceeds the following data at least in one parameter, is classified as cargo - **maximum length of set 16.5 m, maximum width 2.55 m, maximum**

height 4 m and maximum weight 48 t. The maximum load of one axle 8-10 t according to the design of the axle. If the value of any of the given consignment parameters is higher, the consignment is considered as oversized and its transport is subject to special regulations. In the EU, these parameters are identical, only with the exception of maximum weight, which must not exceed 44 t in the EU.

During transport of the oversized item, it is not possible to improvise and change the route; its preparation is a very complicated matter. It contains: [9]

- **Research and design of the route.** It is necessary to analyse the parameters of the oversized item and the parameters of the designed routes including weight and temporary restrictions. It is further necessary to compile a draft schedule and discuss it with competent transport units along the route. It is necessary to negotiate road closures and the draft transport engineering measures with the Police of the CZ,
- Technical escort prescribed for a transport operator registered in the CZ. If the oversized item exceeds the weight limit of 95 t, then two technical escorts are required. If the oversized item is transported by a foreign transport operator, it is necessary to provide a Czech technical escort, the driver of which is acquainted with the draft route and authorised to perform this activity on the territory of the CZ.

3.4. Air transport

Air transport has significant position in cargo transportation. Remarkable is the speed of transfer. Cargo is transported by air on daily bases in scheduled cargo lines or in mixed variations of the aircraft, which transports both passengers and cargo. In comparison with other transport modes, air transport costs are higher. On the other hand, high costs are compensated, in addition to the speed of transport, with lower rate of incidents like thefts, losses and damage, and lower costs for transshipment and storage - shortened logistic chain is applied. Due to high speed and ability to transport large volumes of loads, air transport is also important in the transport of over-sized goods. [5]

In general, it is not possible to determine maximal dimensions or weight, which can be transported by air. To transport shipment a regular cargo line can be used. Limits are set by the type of aircraft, which operates on selected line: its size, shape and entry port dimensions are ultimate. Each load must be considered individually. For example, load which is 3 m height may be suitable for one aircraft, but due to its width may not fit into another. Air loads are typically transported within ULD (Unit Load Device) which represents special pallets or containers with standardized sizes. Most common pallets dimensions are 244 x 318 cm and 244 x 600 cm. Container AMJ has its inner volume limited by 306 x 230 x 240 cm. Cargo aircraft may transport even loads overlapping 100 tons. Frequently used Boeing B747-400F is designed to transport 120 tons of load.

A total of 5 regular cargo airlines serve to and from Prague airport. China Airlines Cargo connects Prague with Dubai and Taipei with freight Boeing 747. Airline Ukraine International Cargo operates the line between Kiev and Liege. FedEx flights to Paris. Outside of winter period it operates in cooperation with TNT Company cargo flights to Katowice. Newest cargo line is set on skyway between German Cologne, Prague and Budapest operated by UPS Airlines.

In case, when final destination or its region is not covered by regular cargo line, it is possible to order individual delivery known as charter flight. For charter flight it is possible to order virtually any type of aircraft. For oversized load with heavy weight is possible to use specially designated cargo aircraft. Biggest aircraft of such type is Ukrainian Antonov An-225 Mriya, which can carry 350 tons - 70 personal cars can be fitted into its interior. Boeing Company designed specially for large freights its Boeing 747-8 Freighter. Its newest version was presented in 2005. Boeing 747-8 Freighter can carry 150 tons of load, which is stored within 853 cubic meters of space.

Over-sized cargo securement on its way is always contingent on individual solution and point of departure and target destination. For each milestone, it is necessary to optimize processes of all subjects in supply chain and its secure program. Most commonly situation is, that final destination is elsewhere than destination airport, which requires to include inter-modal systems, such as air-road conjunction. Combination of transportation reflects natural transport solutions, but nowadays faces also high requirements on fast time demands with its key contribution represented by aircraft. In may 2016 Antonov An-225 Mrija transported from Prague to Australia a giant 117 tons heavy generator of Pilsen company Brush Sem. Generator with its length of 8.8 meters, with over 3.5 meters and height almost 3.2 meters was loaded by two special 40 meters long ramps. Air transport was chosen because of urgent need of Australian company. Antonov on its way to Australian airport in Perth had to land for 3 times to refuel.



Figure 4 Loading of Brush generator into Antonov An-225 Mrija [16]

Each load must go through security check. If load is too big to fit into X-Ray scanner, an additional checks must be taken:

- check of load with explosives detection systems,
- check of load with trace explosive elements detector,
- physical load check,
- check by explosive detection canine team (bomb dogs). [11]

Over-sized shipments are excluded from security control in case they are sent by Regulated agent, Known consigner or Account consigner. In such case, check is executed directly in manufacturing process or during handover from external vendor. Technical assistance is provided as well. Those statuses allows complication free delivery, regulated by EU, and enable to skip security check. Shipments from uncertified companies must be "secured" by additional controls [7] which results into longer transfer times and higher costs. In opposite, freights from known companies are considered as safe by default. Such company must follow European regulations (EU Regulation No 185/2010) as well as to be responsible to fulfill regulations of each individual airport and its security rules, is empaneled by airport operator and certified by Civil Aviation Authority of Czech Republic.

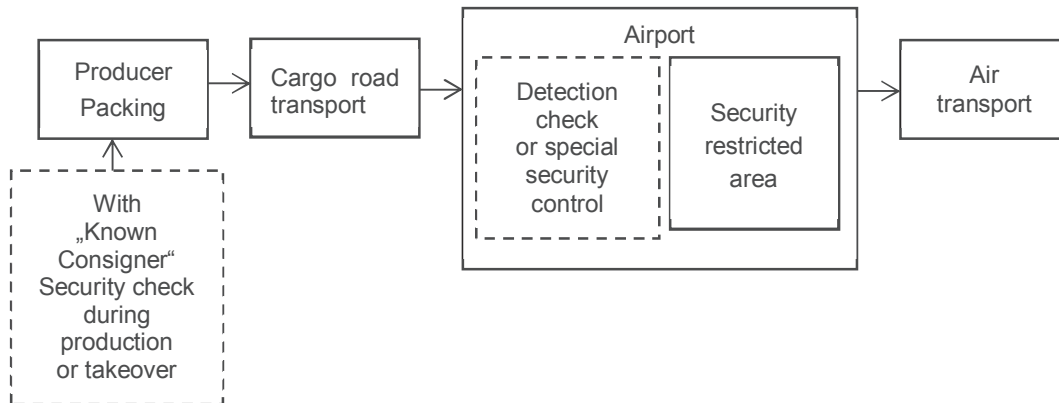


Figure 5 Example of the logistics chain
Source: Authors

4. PROBLEMS OF TRANSPORT INFRASTRUCTURE FOR TRANSPORT OF OVERSIZED ITEMS

In some cases, it is necessary to modify part of the transport route and include such costs in the costs of transport of the oversized item.

4.1. Break-even point

Generally the break-even point means such quantity of company products, where neither profit is gained nor a loss is suffered; total revenue is equal to total costs. If the company reaches this production limit, the revenues shall be equal to the costs.

Formula for calculation of the break-even point: [2]

$$Q = \frac{N_{fix}}{c - n_{var}} \quad (1)$$

c (P) Price per unit

Q Number of units (CZK / time)

N_{fix} (TFC) Total fixed cost (Number of units / time)

N_{var} (V) Unit variable cost

The input data to ensure the break-even point in the given relationship are:

- average transport price,
- transport time,
- loading / unloading time,
- technical downtime,
- average fixed costs of the means of transport / day.

4.2. Analysis of the transport costs of oversized items

Transport of an oversized item is planned in advance before the actual transport, in some cases already during manufacture, also for reason of possible transport in parts. By combination of multiple types of transport modes, it is possible to find the best economic method for transport of an oversized item.

The transport cost of an oversized item is set on the basis of many factors, e.g. current fuel and energy prices, transport distance, size / weight of the oversized item, necessary modification of the route, necessary number

of handling operations and trans-shipments, cost of the technical escort, police escort, charges for recalculation of bridges, eventually, bridge support costs (road transport), etc.

Combined transport costs include loading unto the means of transport at the manufacturer's, road / railway transport costs, trans-shipment at port, storage costs, waterway transport cost from the Czech Republic to the sea port, insurance, assistance services.

4.3. Advantages and disadvantages of transport of oversized items by waterway

Advantages - some oversized items cannot be **transported without waterway transport from the Czech Republic to Hamburg**. Waterway transport has the advantage that the transport route has only minimum limitations for transport of the oversized item and has large capacity means of transport available, which make the transport of oversized items possible, and which cannot be transported by road or railway; it can be used to transport very heavy items of small dimensions thanks to the supporting frames, which are installed in the vessels. The Elbe has a suitable passage profile.

Table 3 Comparison of road and combined transport (road / water) from ČR to Hamburg

Line	Specification oversized items				Transport costs		Comparison
	Length [m]	Width [m]	Height [m]	Weight [t]	Road Transport [CZK]	Combined transport [CZK]	
Ostrava - Hamburg	15	3	3	50	170 000	210 000	23.53%
	15	4	3	50	185 000	220 000	18.92%
	15	5	3	50	280 000	232 000	-17.14%
Brno - Hamburg	15	3	3	50	160 000	200 000	25.00%
	15	4	3	50	170 000	210 000	23.53%
	15	5	3	50	260 000	222 000	-14.62%
Hradec Králové - Hamburg	15	3	3	50	140 000	190 000	35.71%
	15	4	3	50	150 000	200 000	33.33%
	15	5	3	50	240 000	212 000	-11.67%
Pilsen - Hamburg	15	3	3	50	140 000	190 000	35.71%
	15	4	3	50	150 000	200 000	33.33%
	15	5	3	50	240 000	212 000	-11.67%
					Usable		
ČR - Hamburg	15	3	5	50	no	yes	
	15	3 - 5	3 - 5	100	no	yes	
	15	3 - 5	3 - 5	150	no	yes	
	15	3	3	200	no	yes	
	20 - 25	3 - 5	3 - 5	50	no	yes	
	20 - 25	3 - 5	3 - 5	100	no	yes	
	20	3 - 5	3 - 5	150	no	yes	
	20	3 - 5	3 - 5	200	no	yes	
	25	5	5	150	no	yes	

Source: [4] with facts from company Heavy Trans, s.r.o.

Waterway transport has a positive impact on the economic and business sector. It is more ecological than road and railway transport. CO₂ emissions in transport: inland waterway 33.4 grams / tkm; railway 48.1 grams / tkm; road 164 grams / tkm.

In comparison with transport by rail and road, it has a lower noise emission. [3]

Air Transport produces on average 3.15 tons of CO₂ per one ton of burned jet fuel.

The following table shows a comparison of the costs of transport of fictive oversized items on the Czech Republic - Hamburg route. Of the total volume of fictive items, only 3 oversized items can be transported by road from the manufacturer to the sea port of Hamburg. The transport cost rises with increasing dimensions.

Use of railway transport is possible only in combination with another type of transport. When comparing transport costs, road transport is more advantageous than railway transport. However, it is necessary to point out that road transport costs do not include external costs, which according to the study by PLANCO Consulting, are five-fold higher than in the case of waterway transport. [13] For overall evaluation of the advantage of the individual types of transport, it is thus necessary in addition to the price factors to also analyse these external factors that are not paid by the transport operator or contractor at present, but are paid from the state budget.

The most positive factor in air transport of oversized cargo is shortened logistic chain. For complex solutions it is possible to choose offers from many companies specialized in air cargo transport logistics. High costs of air transport are compensated with lower total costs of storage, transshipment and security. Main disadvantage of air transport is the limitation of shape and size of transported freight resulting from the constrained cargo spaces in aircraft. Antonov Mrija is able to transport on top of the fuselage freight up to 70 meters in length and 8 meters in diameter. Inner space allows to fit freight with maximum length 4.4 meters and width 4.3 meters. Other limitation is the fact that the airport of arrival usually does not match with final destination, therefore it is necessary to combine various types of transportation. Even if an airport is close to the destination, it may not have the required runway length. Mrija needs a runway at least 3000 - 3500 meters long. Airport may not have the necessary equipment for loading and unloading of oversize cargo, thus it is inevitable to acquire it from a third party.

Disadvantages - the only disadvantage is the unreliability of the waterway, which is caused by low water, which is moreover unpredictable in time. The Elbe waterway is not navigable over its full length and it is not navigable all-year-round, and it is moreover not possible to predict when navigability shall be guaranteed.

5. MODEL SOLUTION FOR TRANSPORT OF OVERSIZED ITEMS

The manufacturers of oversized items must solve transport to the customer in such a manner as to guarantee the delivery deadline, maintain the characteristics of the product (quality) and minimisation of costs. The entire transport process is influenced by a larger number of factors than apply to the standard type of cargo; it is thus necessary to have the essential professional knowledge and experience with such type of transport, which can only be provided by a team of experts. It is possible when designing the transport process of an oversized item to use a scheme showing the individual activities and decision-making processes.

Table 4 Multi-criteria matrix (columns - criteria, lines - variants) [15]

	k_1	k_2	k_3	$k_{..}$	k_y
V_1	A_{11}	A_{12}	A_{13}	....	A_{1y}
V_2	A_{21}	A_{22}	A_{23}	....	A_{2y}
V_3	A_{31}	A_{32}	A_{33}	....	A_{3y}
$V_{..}$	....	....	....	....	....
V_x	A_{x1}	A_{x2}	A_{x3}	....	A_{xy}

In the general procedure of multi-criteria assessment of the variants, it is necessary to determine:

- a set of criteria (important to achieve the result) - these are criteria where higher values are preferred to lower values:
- criteria weights (also with the help of expert methods); the criterion weight is determined by one expert or a group of experts,
- sample criteria.

Table 5 Mathematical models of the weight of selected criteria

Criterion	Importance	Title
k	the biggest	price
k - 1	.....	reliability
k - 2	.....	time
1	the smallest	safety / security

Source: Authors

It is further necessary to assess the achieved results - assess the individual variants as well as synthesis of these partial assessments into an overall, i.e. multi-criteria, assessment. During assessment, the weights of the individual criteria may be reviewed or the variants may be modified, respectively, increased in number. It is necessary - to assess the risks (by risk analysis), to assess and determine the optimal variant and determine the ranking of the individual variants.

In the event that the selected variant is not fully compliant with the procedure according to the preceding steps, it is necessary to review any of these steps.

Multi-criteria assessment methods [6]

The weight of the individual criteria can be expressed by means of a vector of the weights of the criteria:

$$v = (v_1, v_2, \dots, v_k); \sum_{i=1}^k v_i = 1; v_i \geq 0 \tag{2}$$

The individual variants can be evaluated on the basis of preferential relations:

- the higher the importance of the criterion, the larger its weight in ratio to the rest of the criteria,
- choice of weight must be consulted with the principal, and set priorities in this way. If it is not possible to set priorities, it is necessary to allocate the same weight to each criterion, i.e. the total of all weights must be 100 points, and each criterion (quantity n) thus has a weight of $100 / n$.

It is also necessary to consider whether ordinal information (only determining the ranking of the individual variants) or cardinal information (informs about the difference between the individual variants) is necessary to make the final decision.

To determine the order of the weights, it is possible to use the ranking method, where the i -th criterion is allocated the number b_i (only setting of the ranking of criteria according to importance):

$$v_i = \frac{b_i}{\sum_{i=1}^k b_i}; i = 1, 2, \dots, k \tag{3}$$

v_i weight i -th criterion, where $i = 1, 2, \dots, k$
 knumbers (points), which are allocated to the ranked criteria
 b_i number, which is allocated to the i -th criterion

The total of the b_i number series in the denominator can be calculated using the following formula:

$$\sum_{i=1}^k b_i = \frac{k(k+1)}{2} \quad (4)$$

Table 6 Evaluation of selected cargo transport criteria

Criterion	Type of freight transport				
	Road	Railway	Inland waterway	Seaway	Air
Costs	low	middle	low	low	high
Speed	high	middle	low	low	high
Reliability	middle	middle	middle	high	high
Flexibility	high	low	low	low	middle
Frequency	high	middle	low	low	middle
Universality	high	middle	low	low	low
Sensitivity on climatic conditions	high	middle	low	low	low
Safety / security	high	high	middle	middle	high

Source: Authors with facts from [1]

In the model of economic transport costs for each edge, the transport cost in the section defined by the individual graph edges are adjusted by the criteria for the parameters of the given transport route section (capacity, reliability, speed, safety, trans-shipment method, storage charges, etc.). The scheme of this model is shown in the next figure.

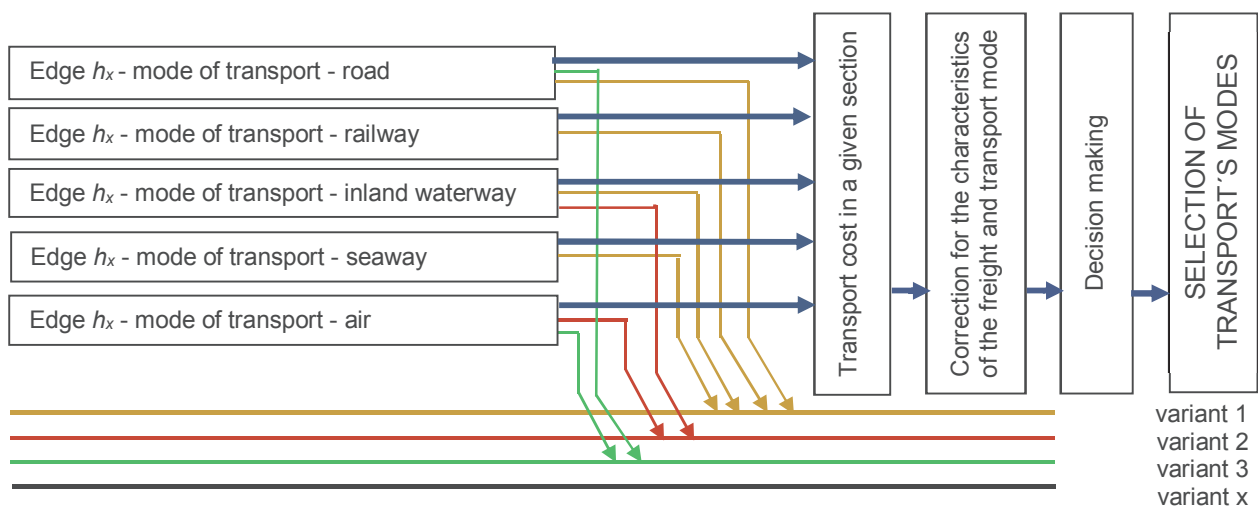


Figure 6 Model of economic transport costs for each edge

Source: Authors

In some cases, however, route length is not in first place, and optimisation of the selected route in terms of the time and price combination take precedence. Although the shortest route search model is the simplest, it is however necessary to search just for the combination stated above.

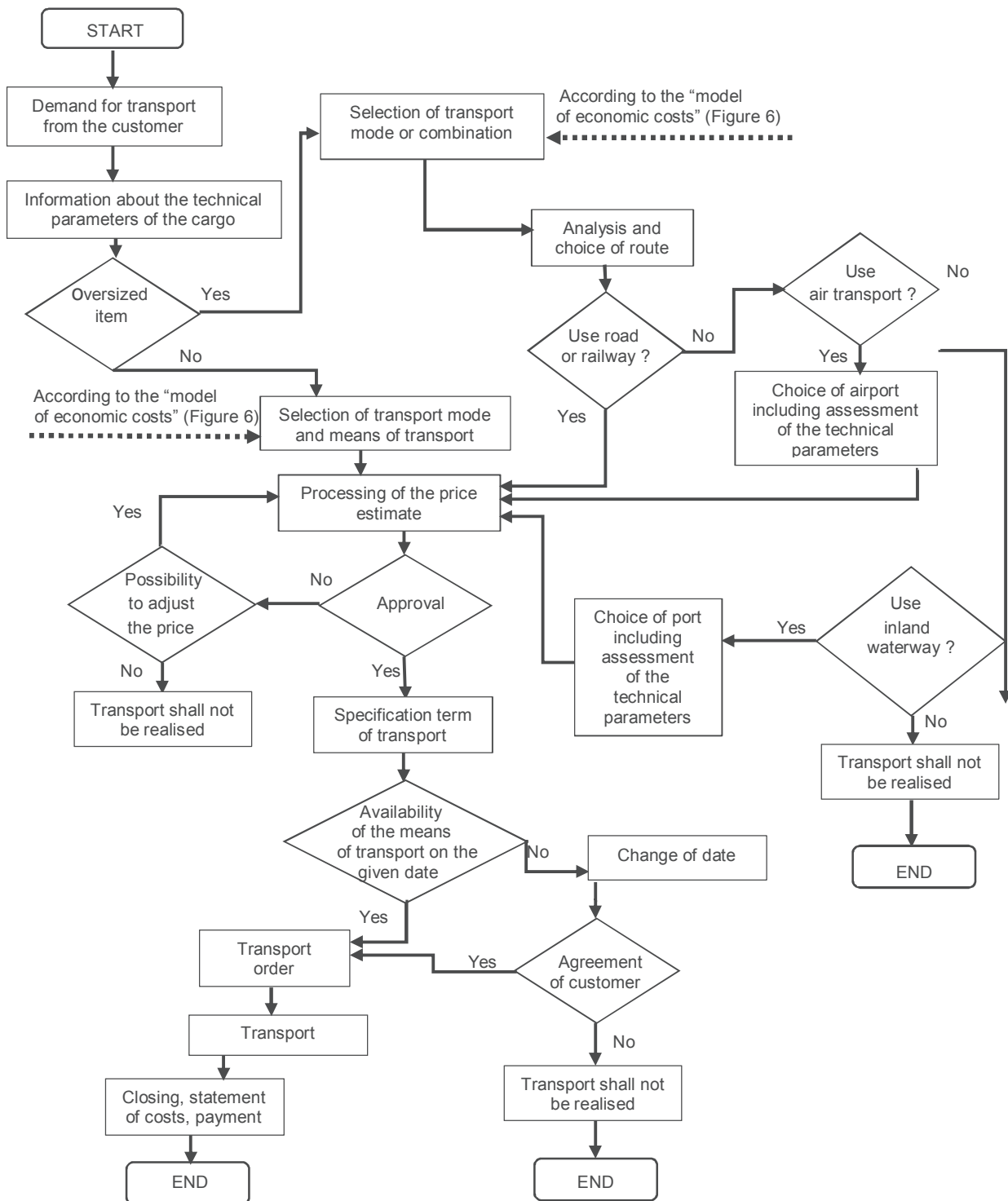


Figure 7 Transport mode selection scheme for oversized items

Source: Authors

6. CONCLUSION

Transport of oversized items is a difficult task that requires teamwork. During the process of transport planning, several decisive moments exist. The objective is to get the oversized item to the destination in Europe or even overseas.

If a comparison of the characteristics of the individual transport modes is made, it is possible to state that inland waterway transport is irreplaceable because it is not fraught with limiting parameters (excluding wholly exceptional cases), which would exclude this type of transport. In the economic assessment of the costs of the Czech Republic - Hamburg route, the cheapest combination is road transport to an inland waterway port and inland waterway transport to the sea port.

Inland waterway transport has always been considered as the most important transport mode for oversized items and it still has this status. However, cases exist in which the transport price is not the most important criterion, respectively delayed delivery could entail a substantial financial loss. In such case, particularly for overseas transport, it is also possible to opt for air transport.

An important criterion of air transport is its reliability in terms of the delivery deadline, unlike inland waterway transport in the Czech Republic, which exhibits substantial unreliability in this aspect. The advantage of inland waterway transport continues to be the lower price level as compared to the rest of the transport modes.

The issue therefore remains the problem of navigability of the Elbe waterway, which is not only currently, but also historically a significant transport connection with Western Europe.

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