The Decision Tree Approach for the Choice of Freight Transport Mode: The Shippers' Perspective in Terms of Seaport Hinterland Connections

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Abstract:

Purpose: *Current research in the area of transport decisions indicates that the key factors decisive for the mode choice are the cost and the time of transport. The complexity of behaviours and preferences of cargo shippers as well as the diversity of supply chain configurations, along with unavailability of an appropriate dataset hinder reliable forecasting the demand for transport and planning its development by means of quantitative methods. The aim of this article is to identify the factors that affect the decisions on mode choice by cargo shippers, based on data obtained by means of a qualitative method.*

Design/Methodology/Approach: *The decision tree methodology was used in the analysis of the research study. To analyse the decision tree on the basis of C4.5. algorithm, the authors applied the J48 module of the WEKA 3.8.4. software.*

Findings: *The research has shown that the major attributes in selecting transport modes by cargo shippers, taking into account access to three modes of transport to the seaports hinterland, are consignment size and time pressure, then owning or having access to barge terminals by cargo shippers, and the annual volume of cargoes generated by them.*

Practical Implications: *The results of the analysis can be useful for managers of supply chain making decisions regarding the choice of transport route.*

Originality/Value: *The developed decision tree model provides cargo shippers with a possibility of choosing three transport modes to carry cargoes to/from the seaports: road, rail, and inland shipping, which constitutes supplementation and expansion of the studies completed so far, which usually took into account only rail and road transport.*

Keywords: *Decision tree model, transport mode choice, seaport hinterland transportation.*
JEL codes: *M15, M20.*
Paper type: *Research article.*

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1. Introduction

Transportation modelling is an integral part of forecasting the demand for transport (Samimi *et al.,* 2012). Mode choice is the third out of four main stages of transportation modelling which covers trip generation, trip distribution, mode choice, and assignment (Ortuzar and Williumsen, 2006). With regard to seaports and their connections with the hinterland, Halim *et al.* (2016) indicate that availability and quality of port-hinterland connectivity plays a major role in choosing such ports by cargo shippers. The mode structure as well as the quality of port-hinterland connectivity also affect decisions taken by cargo shippers with regard to selecting the transport mode to/from seaports. Consequently, the strategic decisions made by cargo shippers and providers of transport and logistics services with regard to selection of hinterland transport mode, location of distribution centres, and connections between the distribution centres and transport infrastructure have an impact on the hinterland transport structure, and thus strongly influence the seaport connectivity.

The current research studies on the issues of transport decisions mostly apply the optimisation approach and models of discrete choice based on big data analyses. At the same time, the academic literature points out to the complexity of behaviours and preferences of cargo shippers, as well as the diversity of supply chains configurations, along with unavailability of appropriate datasets, which hinder reliable forecasting the demand for transport and planning its development by means of optimisation approaches and discrete choice models (Cunningham, 1982; De Jong *et al.* 2004). In this context, the qualitative multi-criteria decision tree methods based on data obtained from direct research and various decision tree models developed on their basis are deemed to be very easy to construct and interpret, and to have considerable cognitive value and practical usefulness (Samimi *et al.,* 2012). Still, they are rarely applied in researching the decisions of cargo shippers regarding mode choice in transport to/from seaports.

The aim of this article is to identify the factors that affect the decisions on choosing transport modes by cargo shippers located in the seaports hinterland, based on the data obtained by means of a qualitative method (in-depth interviews among shippers located in the hinterland of the Polish seaports of Szczecin and Świnoujście). As the developed decision tree model applies the data derived from direct research, the model to a larger extent covers complex behaviours and diverse preferences of cargo shippers, which have a key impact on transport decisions made by them.

The research results are presented in the form of a decision tree. The developed decision tree model provides cargo shippers with a possibility of choosing three modes of transport to carry cargoes to/from the seaports: road, rail and inland shipping, which constitutes supplementation and expansion of the studies completed so far and taking into account only rail and road transport.

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2. Literature Review

A considerable part of research studies completed so far in the area of port-hinterland connectivity focused on developing the systematics and conceptualisation of port-hinterland distribution systems (Van den Berg and De Langen, 2011; Rodrigue and Notteboom, 2010; Notteboom and Rodrigue, 2017; Chislov *et al.,* 2019). The research studies on transport decisions made by cargo shippers, also regarding haulage to/from seaports, apply mainly quantitative methods, such as the optimisation approach, and discrete choice models taking into account predominantly the cost and time aspects (Thore and Iannone, 2012; Iannone, 2012; Guand Lam, 2013; Nam and Win, 2014; Ferrari *et al.,* 2011; Wang *et al.,* 2016; Tundys *et al.,* 2018).

However, Samimi *et al.* (2012) point out that the optimisation approaches require large amounts of data and are not easy to formulate and solve in practice, whereas discrete choice models have certain unavoidable statistical assumptions such as linear property of utility function and pre-defined structures (e.g. probability distributions), which to a certain degree make it impossible to reliably estimate mode choice behaviours. Therefore, qualitative and multi-criteria methods are more and more often applied to study transport decisions and mode choice behaviour.

A more in-depth research study in this respect, applying the qualitative approach to a larger extent, was carried out by Halim *et al.* (2016) who developed a strategic model of a network of distribution of cargoes between the port and its hinterland, taking into account the preferences of cargo shippers and the structures of the port-hinterland logistics systems (a strategic model for port-hinterland freight distribution networks).

Also, the multi-criteria methods are gaining popularity, including the methodology of *decision trees, due to their simplicity* and considerable cognitive value. The decision tree methodology is to a larger extent applied in the research studies regarding the mode choice in passenger transport (Oral and Tecim, 2013; Janssens *et al.,* 2006; Rasouli and Timmermans, 2014; Tang *et al.,* 2015). However, the decision tree methodology is rarely used in research studies in the area of freight transport mode choice and the issue of port-hinterland connectivity (port-hinterland oriented freight network models). Simultaneously, the usefulness of the decision tree methodology in the analyses of cargo flows was confirmed by the studies carried out by Thill and Venkitasubramanian (2015) to explain the nature of inter-port competition in three dimensions, space, commodity types and shipment values.

Interesting studies applying the decision tree methodology in transport decisions made by cargo shippers were also carried out by Samimi *et al.* (2012) in the USA. The authors took into account attributes such as origin, destination, mode of transportation, type, value, weight, and volume of the commodity. The studies included two modes of transport or their combinations truck only, rail, or rail

intermodal. Using various decision tree models, the authors proved that there is a merely 9% chance of choosing rail instead of road transport. The authors have also pointed out that long-distance, heavy and containerised cargoes gravitate more to rail transport, and consignment weight is the most important attribute that influences the decisions on selecting a transport mode.

The research studies described in this article cover three hinterland transport modes: rail transport, road transport, and inland shipping, which makes it possible to verify and expand the studies completed so far, using multi-criteria methods (Samimi *et al.,* 2012). Thus, the research results presented in this article supplement the theoretical knowledge regarding the scope of choice from among the three transport modes (rail, road, barge) by cargo shippers located in the seaports hinterland, with the use of the decision tree methodology.

3. Methodology

The decision tree methodology is one of the most popular decision support methods (Quinlan, 1990). A decision tree is a structured tree with a root node from which decision nodes branch out. Each decision node has one branch coming out of the root node or a higher level decision node, and two or more branches leading to lower level decision nodes or a leaf node. A leaf node is the last node which constitutes the class label, i.e. the final decision result.

In order to develop a decision tree showing the decisions of cargo shippers making their choices regarding transport modes to be used to carry cargoes to/from the seaports, we applied Quinlan's (1990) algorithm C4.5, which is an extension of the basic algorithm ID3 (Dai and Ji, 2014). The advantage of algorithm C4.5 compared to algorithm ID3 is a possibility of creating a decision tree based on attributes whose values do not have to be binary, moreover, it applies the pruning method, i.e. pruning during the construction of trees to avoid over-fitting (Li and Hu, 2008). The J48 module of the WEKA 3.8.4. software programme was used in order to develop the decision tree.

The first stage of the research study was developing a database containing the factors that are decisive for selecting a transport mode by cargo shippers. The database was developed on the basis of the direct research study involving cargo shippers located in the hinterland of the seaports of Szczecin and Świnoujście (Poland), which was carried out in the form of standardised direct interviews in 2017. The purpose of the research was to specify the potential demand for inland shipping to/from the seaports of Szczecin and Świnoujście, as an alternative to road and rail transport, in view of the planned upgrading of the waterway leading to the seaports (the Oder Waterway). The Oder Waterway is now practically not used as a hinterland transport mode to/from the said seaports due to its unsatisfactory technical parameters. Consequently, the completed research studies also helped to

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verify the existing knowledge in the area of competitiveness factors of hinterland modes of transport in land-sea transport chains.

The direct interviews were held among 18 maritime exporters and 22 maritime importers. The interviewees were identified by means of the targeted selection method, and they concomitantly met the following conditions:

1) running business activity in the catchment area of the seaports in Szczecin and Świnoujście, i.e. in the provinces of Lubuskie, Wielkopolskie, Dolnośląskie, Opolskie and Śląskie (the analysis did not include cargo shippers from the Zachodniopomorskie due to the small distance to the seaports (<250km), which makes their cargoes naturally gravitate to road transport)
2) location within a distance of no more than 50 km from the route of the Oder Waterway, so that all the entities have a potential access to the three modes of hinterland transport, rail, road, and inland shipping
3) generating annual cargo shipments to/from seaports at the level of 10,000 tonnes or more.

The cargo shippers were identified on the basis of the official data obtained from the Department of the Analytical Centre of the Tax Administration Chamber in Warsaw (DACTAC CAAC, data for 2016). The interviews were held with representatives of all the business entities that exported or imported more than 100,000 tonnes of cargo per year (7 exporters and 7 importers) as well as 26 entities that generated transport volumes within the range from 10,000 to 100,000 tonnes per year (11 exporters and 15 importers). These included both primary cargo shippers (manufacturing companies that export their products or import raw materials/ components) and secondary cargo shippers (intermediaries) who imports goods for other entities or export their products. The group of entities covered by the study was representative for the potential of the hinterland of the analysed seaports in Szczecin and Świnoujście. The study involved all the entities that determined their transport needs to exceed 100,000 tonnes of cargo per year, and over 70% of the entities that generated annual cargo volumes from 10,000 to 100,000 tonnes to be carried to/from the said seaports.

The obtained responses were applied in creating a database containing 47 instances (seven cargo shippers make use of two transport modes depending on the adopted values of attributes). The developed database included the following attributes and values corresponding to them:

@attribute annual_volume {>100.000,10.000-100.000}
@attribute distance {>600,400-600,<400}
@attribute consignment {>1500,250-1500,<250}
@attribute time_preasure {yes,no}
@attribute barge_port {yes,no}

@attribute producer {yes,no}
@attribute transport {rail,barge,road}.

The database was the source of data for the developed decision tree. In the WEKA software, the "training set" option was applied, which is used to create descriptive models in the case of having a database containing all attribute values (Brownlee, 2014).

The analysis was supplemented with additional factors affecting the mode choice, which resulted from specific external and internal determinants of a given cargo shipper. The factors were classified in three groups, technical, economic and organisational, and assigned to the individual transport modes.
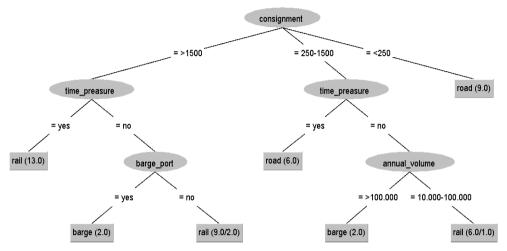
4. Results

The decision tree developed on the basis of the obtained data is presented in Figure 1. There were 44 correctly classified instances, which accounted for 93.617% of all. The research results processed by means of the decision tree method indicating that the basic attributes in choosing the transport mode by cargo shippers, in the case of having access to the three modes of transport between the hinterland and the seaports (rail, road, barge), are as follows: consignment size, time pressure, possessing or access to barge terminals by cargo shippers, and annual volume of generated cargoes.

The detailed determinants of the mode choice to be made by cargo shippers in the seaport hinterland, identified during the primary research study, are presented in Table 1. Their impacts depend on the volume of a single consignment (small < 250 tonnes, medium 250–1500 tonnes, large > 1500 tonnes), additionally in the case of medium consignments that do not need fast delivery, their annual volumes (medium 10–100 thousand tonnes or large > 100 thousand tonnes). The analysis has shown that most cargo shippers transporting their cargoes in consignments exceeding 1500 tonnes available themselves of rail transport. The factors decisive for choosing rail transport include:

1. considerable carriage distance (>300 km),
2. considerable annual volume of homogeneous cargoes, regardless of their kind: bulk cargo, general cargo, or containerised cargo (from several dozen thousand tonnes to several million tonnes),
3. one-off consignments at the level from 1.5 to 2.3 thousand tonnes.

The research study has shown that rail transport was the optimal transport mode for dry bulk cargoes vulnerable to damage or shrinkage during transshipment (e.g. brittleness, powder consistency). A limited number of transshipment operations in the case of direct haulage makes it possible to preserve the appropriate quality of the commodity.

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Figure 1. *Decision tree for transport mode choice to be made by cargo shippers in the seaports hinterland, generated in the Weka 3.8.4 programme, with the use of the J48 algorithm*

Source: Own work.

Cargo shippers that generate more than 100,000 tonnes of cargo per year are inclined to choose rail transport due to the preferential treatment of this customer group by rail operators. According to the interviewed cargo shippers, rail transport is fast, cheap, safe and reliable.

The factors affecting the choice of rail haulage in this group of cargo shippers and some cargo shippers that generate annual cargo volumes at the level of 10–100 thousand tonnes included the infrastructural conditions such as a direct access to the rail transport infrastructure via a railway siding on the premises and its capability (provided already at the stage of construction of the industrial plant) to handle rail transport (e.g. having railway turntables in place), or not having own storage space (using specialised rail wagons to store cargoes on the premises).

The organisational factors that facilitate choosing rail transport by cargo shippers include:

1. possibility of transporting, within a short time, a consignment which can be directly loaded onto a coaster vessel in a seaport or which, upon placing in a storage yard, may be loaded via an indirect system onto a panamax vessel, and be taken out of the port,
2. possibility of transporting, within a short time, a consignment of several tens of thousand tonnes of cargoes from a seaport to the cargo shipper's premises in the port's hinterland,

Table 1. *Factors determining the mode choice by cargo shippers in the seaport hinterland*

Determinants		Rail transport	Inland shipping	Road transport
Tech nical	infrastruc tural	- adapting the premises to rail transport handling - not having own specialised storage space	- having an own inland port - a need to use intermodal transport due to the lack of own railway siding	- adapting the premises to road transport handling - not having own storage space
	physical and chemical features of cargo	- specific features of the cargoes that require minimisation of transshipment operations	- cargoes not vulnerable to damage in the course of numerous transshipment operations - consignment sizes that enable involvement of rail haulage	- sensitive cargoes requiring controlled temperatures
Organisational		- short pre-carriage time of a consignment to the seaport to be directly transshipped onto a coaster - short pre-carriage time of a consignment to the seaport to be indirectly transshipped onto a panamax vessel - short on-carriage time of cargoes from the port, which occur occasionally in large maritime consignments - making use of a comprehensive service offered by an intermodal operator - capital ties between the cargo shipper and the rail operator	- unattractive rail freight transport offer for the cargo shippers who declare a need for transport of large, single consignments, but not frequently - a cargo shipper's positive experience regarding inland shipping used in other divisions of the company - short distance to the seaport (100 km) - perceiving inland shipping as the safest transport mode by shippers of some specific kinds of cargoes	- a need for fast movement of cargoes to/from a seaport - a need for transporting small or medium consignments on an irregular basis - dispersed activities of the cargo shipper - considerable dispersion across the hinterland of customers of cargo shippers acting as intermediaries - considerable diversity of kinds of cargoes handled by any given cargo shipper acting as an intermediary
Economic		- attractive haulage rates for cargo shippers generating large annual cargo volumes - connection between the time of transporting the cargo to the seaport and payment made by the contracting party (importer) - concerns of cargo shippers who annually generate medium cargo volumes, fearing that rail transport rates can increase as a result of modal diversification of freight transport - reliability of long-term, fixed rate freight service - minimising the cost of frozen capital and a low risk of incurring penalties to be paid to customers as a result of downtime	- low freight rates and a low risk of losses resulting from frozen capital in case of short freight distances - no concerns among cargo shippers generating large annual cargo volumes about negative effects of modal diversification of transport in the context of contracts with rail freight operators - providing a possibility of transport for cargoes which due to their low value are not suitable for rail or road transport - making occasional deliveries of project cargoes	- a too small consignment (below 1500 tonnes), unattractive to a rail or barge operator - a high unit value of a consignment - savings resulting from not having to keep own storage space - cargoes imported on DDP terms - cargoes of unusual size and weight, stored in bonded areas, where it is the final customers, not the cargo shipper being the importer, who are responsible for transporting the goods to the seaport's hinterland

Source: *Own work.*

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3.   capital ties between a given cargo shipper and a rail operator or an operator in the seaport, who does not have an inland shipping infrastructure,
     a need to use the services of a specialised intermodal operator who will take over the whole organisation of the transport process (taking the cargo over from the cargo shipper's premises and transporting it to the seaport/ intermodal terminal).

The economic factors that facilitate choosing rail transport result from, among other things:

1.   advantageous rail freight rates offered by rail operators to cargo shippers who generate considerable annual cargo volumes,
2.   attractive terms and conditions of freight carriage are binding throughout the whole period (e.g. a year) for which the contract was concluded (including the winter period),
3.   concerns of cargo shippers who generate smaller cargo volumes, fearing that attempts to diversify the transport solutions (e.g. via partial use of inland shipping) will contribute to increased freight rates that may be offered to them by rail operators,
4.   minimising the frozen capital by cargo shippers and limiting the risk of penalties to be paid to contracting parties due to rail transport capabilities of carrying considerable cargo volumes within a very short time (payments made by importers on the day following the day on which the vessel with cargo leaves the port of departure) and the low risk of downtime on the transport route (no traffic jams).

The factors have contributed to achieving by rail haulage a competitive advantage over other transport modes.

Inland shipping is perceived as an opportunity mainly by those cargo shippers who make deliveries in medium and large consignments – above 250 tonnes, and none of the shippers has declared that inland shipping may be the only mode of transport to carry cargoes to/from the seaports. This results mainly from the low reliability of delivery attributed to inland shipping, while it is considered a necessary condition for shifting cargoes from other modes of transport (Kotowska *et al.,* 2018). The factor that affects the reliability of delivery by inland shipping is navigation closed periods when deliveries are not made.

The carriers who indicated inland shipping as the dominating mode of transport have a direct access to the infrastructure (possibility of carrying cargoes directly between the seaport and the shipper's premises), which in view of competitive haulage rates (in relation to rail haulage) translates into considerable financial gains. Simultaneously, such cargo shippers are not under time pressure in connection with a longer time of inland transport in relation to rail haulage or they are located relatively close to the seaport, so rail operators are unable to achieve an advantage in

terms of transport time. Also, the shippers who generate the largest annual freight volumes are not concerned that making use of inland shipping services will contribute to being offered worse transport terms and conditions (increased cost rates) by rail transport operators. Inland shipping would be readily used by the cargo shippers who are not the priority customers to rail transport operators. These are mainly the shippers who do not generate full train consignments and the ones who generate whole train consignments, but not very frequently (e.g. once a month).

These cargo shippers often have to wait for a long time to have any wagons provided for loading, they cannot count on short delivery times or preferential rates, therefore they are inclined to search for alternative solutions. The price advantage of inland shipping may enable trading (and consequently transporting) cargoes whose haulage with other transport modes, due to their very low value, would not be economically viable (e.g. sawmill waste). Inland shipping has an undeniable competitive advantage in the case of transporting project cargoes, e.g. for replacing plant and equipment in industrial facilities. Compared to other modes of transport, inland shipping easily handles large unit weights and larger cargo sizes, therefore cargo shippers more readily use this mode of transport as long as the minimum navigation requirements are met. Some cargo shippers from the chemical sector also consider inland shipping to be the safest form of transport.

Road carriage is selected by cargo shippers to transport small or medium consignments featuring:

1) greater time sensitivity (e.g. due to the lack of storage space on the premises or closeness of the overseas markets of the origin or destiny of the cargo),
2) greater dispersion of deliveries due to multiple premises or the changing range of the cargo shipper's business activities,
3) considerable dispersion of customers (in the case of cargo shippers being intermediaries) and ensuing break-up of cargoes,
4) high diversity due to the degree of unitising in the transport process (cargoes of the same kind, e.g. fertilisers carried both in bulk and in unitised forms),
5) high unit value (e.g. technologically advanced cargoes with high unit prices explicitly gravitate to road transport).

Due to the developed road transport infrastructure, each cargo shipper has a good or very good access to this mode of transport. Means of road transport are able to meet the requirements that are impossible for other modes, in particular with regard to handling cargoes that are temperature sensitive (e.g. when a cargo has to be heated throughout the time of carriage).

In the case of the smallest consignments, road transport does not experience a competitive pressure of other modes of transport which are unable to offer

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competitive price terms for such consignments. Just-in-time deliveries also make it possible for cargo shippers to obtain savings, as they do not need to maintain extensive storage capacities. In the case of cargoes stored in bonded areas, which are problematic in terms of transport organisation (a large share of freight costs in the value of the cargo itself, atypical dimensions, heavy weight), cargo shippers sell them to final recipients and require them to organise the transport themselves (due to the dispersion of consignees and the aforementioned characteristics of the cargoes, the consignees are inclined to choose road transport). Road transport was also chosen by cargo suppliers on DDP terms, where cargoes are delivered to the importers' premises.

5. Conclusions

Most research studies completed so far in the area of making transport decisions indicated that the key factors decisive for the mode choice are cost and time of transport. The existing, more in-depth studies, accounting for cargo shippers' preferences, took into account only the two modes of transport, road and rail. Our study carried out with the use of the decision tree methodology, based on the primary research study on the preferences of cargo shippers located in the seaports hinterland, took into account three modes of transport, road, rail, and inland shipping, which had a big impact on transport decisions. The research studies have shown that the major attributes in selecting transport modes by cargo shippers, taking into account an access to the three modes of transport to the seaports hinterland, are single consignment size and time pressure, then owning or having access to barge terminals by cargo shippers, and the annual volume of cargoes generated by them.

The study has shown that the greater the frequency of requests to transport large consignments (above 1500 tonnes), the higher the inclination of cargo shippers to choose rail haulage, which is additionally enhanced by a greater time pressure for transport. Analogously, in the case of large single consignments, the smaller the time pressure, the higher the inclination of cargo shippers to use inland shipping. An issue of key importance for the final choice of rail transport instead of inland shipping is having a barge terminal, or an access to it, by the cargo shipper.

In the case of medium single consignments (250–1500 tonnes), also the attribute of time pressure is of key importance. Also, in the case of this cargo group, the higher the time pressure, the higher the inclination of the cargo shippers to make a decision on choosing road rather than rail haulage. Simultaneously, lack of time pressure inclines cargo shippers to consider rail haulage and inland shipping in their transport decisions. Another factor affecting the choice is the annual volume of transport. Smaller annual volumes are more likely to gravitate to inland shipping, due to the tariff policies provided by rail operators who offer better terms to cargo shippers that generate a higher annual demand for transport.

In the case of small single consignments (less than 250 tonnes), the studies have shown that road transport is the only option taken into account in decisions made by cargo shippers.

The analysis of the transport decision making process has also indicated that in many cases the choice of a transport mode is affected by individual factors that recur only in the case of some cargo shippers, i.e. capital ties with a specific port enterprise (which does not have access to all modes of transport) or a transport company, the unit value of the cargo, its physical and chemical properties, and the transport safety level. The two latter aspects are usually a result of a very subjective evaluation by the cargo shippers of various cargoes showing different physical and chemical properties. For some, road transport will be safer, as the driver supervises the cargo at all times (high value cargoes), for others inland shipping is safer, as the carriage takes place away from residential areas (hazardous cargoes), while some other shippers think that rail is the safest mode of transport due to the limited number of transshipment in the transport process, which decreases the risk of cargo quality deterioration (limited shrinkage). Due to the multitude and subjective character of the factors indicated above, not all of them could be accounted for in the developed decision tree, even though they have a significant impact on transport decisions made by particular cargo shippers.

The research study has also shown that not all attributes included in the study by the authors were relevant when choosing the transport mode to carry cargoes to/from seaports. For loads carried over distances greater than 250 km, the transport distance does not affect the choice of route. Similarly, the type of shipper(manufacturer or trading company) does not affect the transport route. Trading companies rarely have access to railway sidings, and their deliveries are more scattered. The use of the decision tree method made it possible to eliminate the less relevant attributes.

A constraint of the applied decision tree method was a relatively small number of studied entities, nevertheless it was representative, taking into account the potential of the hinterland of the seaports covered by the study. The study involved all the entities that generate more than 100,000 tonnes of cargoes per year, and most of their cargoes was part of the Polish maritime trading.

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