OPTIMISATION OF THE EXPORT STRUCTURE IN TRANSPORT COMPANIES: A CASE STUDY

Shpak, N., Dvulit, Z., Maznyk, L., Sroka†, W., Zaverbnyj, A., Levchenko, O.

Nestor Shpak / Lviv Polytechnic National University, Department of management and international business, 12 Bandera str., Lviv, Ukraine. Email: nestor.o.shpak@lpnu.ua

Zoriana Dvulit / Lviv Polytechnic National University, Department of foreign trade and customs, 12 Bandera str., Lviv, Ukraine. Email: zoriana.p.dvulit@lpnu.ua

Liana Maznyk / National University of Food Technology, Department of labour economics and management, 68 Volodymyrska str., Kyiv, Ukraine. Email: solieri@i.ua

Włodzimierz Sroka† / WSB University, Dąbrowa Górnicza, Faculty of Applied Sciences, Department of Management, Dąbrowa Górnicza, Poland & University of Johannesburg, South Africa. Email: wsroka@wsb.edu.pl

Andrij Zaverbnyj / Lviv Polytechnic National University, Department of foreign trade and customs, 12 Bandera str., Lviv, Ukraine. Email: andrii.s.zaverbnyi@lpnu.ua

Olha Levchenko / State University of Infrastructure and Technologies, Faculty of Navigation, Department of Infrastructure and Innovative Technologies of Water Transport, 9 Kyrylivska str., Kyiv, Ukraine. Email: olevchenko76@gmail.com

Abstract

With the increasing complexity of economic systems caused by the intensification of European integration processes and the general globalisation trend, the problems of ensuring the optimal operation of transport companies are becoming especially important. Given these facts, the article's purpose is to develop and test a structural modelling algorithm based on the system state indicator (entropy of the structure of the export freight system). Research methods used in the article include: statistical (structure and dynamics analysis), systematisation and comparison, system analysis methods (entropy characteristics), and mathematical programming methods. The mathematical formulation of problems involves studying structural uncertainty due to the synergistic influence of interconnected structures. As a result of the optimisation calculations, the entropy index decreased as a consequence of the optimisation of the studied structures of export cargo. The study results using structural-dynamic modelling provide an opportunity to determine benchmarks for optimising the structure of export transportation. Therefore, they can act as indicators in the relevant field to substantiate the performance of large transport and logistics companies. The use of such approaches will help improve cooperation on a shared basis between Ukraine and the countries of Central Europe.

Implications for Central European audience: first of all, the algorithm of structural modelling containing stages is offered (structural-dynamic analysis; systematisation of the reasons that led to structural changes; mathematical formulation of the optimisation problem; numerical solution of the problem; interpretation of results and development of

recommendations) as the theoretical contribution. Moreover, it has prospects for implementation by European transport companies, as the strategic partners of Ukraine in the field of rail freight are the Central Europe countries. In turn, practical implications include: to test the proposed model, the process of forming the structure of export freight JSC "Ukrzaliznytsia" as a partner of big Central European export companies was chosen as the object of study.

Keywords: entropy; export; freight transportation; optimization; modeling; structure; system
JEL Classification: C50, L16, L92, C61

Introduction

The country's global competitiveness in international markets is determined by its ability to ensure a certain level of development and the capacity to maintain this position. According to the Global Competitiveness Index (World Economic Forum, 2019), Ukraine has been ranked below 80th out of 140 possible for many years, in terms of infrastructure – below 50th. In terms of macroeconomic stability, Ukraine was ranked 131st in 2018 and dropped to 133rd in 2019 (out of 141 possible). Achieving and maintaining the desired level of macroeconomic indicators of the country can be achieved through the optimisation of export activities as a catalyst for the sustainable development of the transport industry (Kral et al., 2018). Sustainable development of the country in this context can be considered through the harmonious development of certain sectors of its economy, including infrastructure sectors. The infrastructure industries are able to improve their position in global rankings as an indicator of the level of sustainability of development.

Railway enterprises are one of the main branches of the Ukrainian economy and the most important component of the transport system. Railway transport of Ukraine has an operational length of railways which is more than 20,000 km, and it occupies a prominent place among railway companies in Europe. Ukraine's rail transport ranks fourth in the cargo transportation rating on the Eurasian continent. Only China and India are ahead by this indicator. Seven countries of the world are neighbours of Ukraine (Belarus, Poland, Hungary, Russia, Slovakia, Romania, Moldova), with which it is connected by rail transport corridors, including more than 50 border crossings. Of all modes of transport, the lion's share of cargo transportation belongs to railway transport, and it is almost 82%. Only 18 % of these transportations are realised by other modes of transport (road, water, air) (The main aspects of the Development Strategy of JSC "Ukrzaliznytsia" 2017-2021, 2021).

Given that railway transport belongs to the most important sectors of the Ukrainian economy, its sustainable development is of crucial importance. One should add that sustainable development requires green investments, which are more expensive than traditional investments (Moldovan, 2015). Research on the problems of sustainable development of railway transport, its main advantages over other modes of transport, as well as the main problems and challenges from the standpoint of the concept of sustainable development, are raised by Dvulit and Levchenko (2017). In this study, the authors draw on the proposed concept of sustainable development of railway transport enterprises as a

system of interconnected components that balance the production and economic activities of such enterprises for the needs of the state's economy. This involves determining the optimal export structure. At the same time, sustainable development is considered a structural definition of the ratio of the whole (sustainable development of the country) and the part (sustainable development of the railway industry by type of activity, one of which is export cargo transportation by railway transport enterprises). Export as a type of foreign economic activity is a factor in ensuring such an important macroeconomic indicator of the country as Gross Domestic Product (GDP). Firstly, export is a factor in the formation of macroeconomic indicators. Secondly, it is a factor indicating the degree of involvement in the international division of labour. And thirdly, it has a synergistic effect on all sectors of the economy and, as a consequence, on ensuring the sustainable development of the country. As Meyer (2021) claims, many countries have successfully facilitated rapid growth via the export-led growth nexus, and diversification and specialisation are essential components of exports (Szczepaniak, 2018). Therefore export activities require support by the state (Richter, 2015). Furthermore, physical capital plays a critical role in the success of a country's exports. The government uses the budget to invest in public infrastructure, for example, roads and transport infrastructure (Le, 2022). Exports are an integral part of the overall economic potential of any state and largely determine the pace of its economic development (Pancenko & Ivanova, 2018), and there is a positive correlation between the export of goods and gross regional product (Horská et al., 2019). Therefore, to optimise the management of export activities, the authors proposed to use expert methods to obtain initial data, which are further the basis for determining adequate directions (Richter, 2015). In turn, Petrová et al. (2021), as well as Ključnikov et al. (2022), study the impact of risks on export activities. They suggested choosing additional information and the results of a study of the relationship between risk assessment and exports as a risk management tool. And Li (2018) proposes a comprehensive approach to studying the dependence of export dynamics on the interaction of entrepreneurial resources with institutional dimensions.

This review shows how complex and multidimensional is the said problem. Given these facts, the article's purpose is to develop and test a structural modelling algorithm based on the system state indicator (entropy of the structure of the export freight system). The remainder of the paper is structured as follows. The next section presents a literature review devoted to the problem. This is followed by the presentation of the research methods applied by the study. In turn, the next section presents the research results and discussion. Finally, we conclude as well as present the limitations of our study.

1 Literature review

1.1 Theoretical background

The works of many scholars are devoted to studying the directions of optimisation of the structure of the transport system. Most of them analyse individual factors influencing the activities of transport companies. These include: technical, political, economic, social, regional, environmental, the degree of development of information and communication technologies, the quality of transport management, and the ratio of export-import activities. (e.g. Shpak et al., 2018; Shpak et al., 2021a; Prokopenko et al., 2020a; Kolarov & Georgieva, 2020). For example, the main factors influencing the general organisation of the

state of transport and logistics without taking into account the types of connections are investigated by Mindur and Hajdul (2013) and Prokopenko et al. (2020b). The main aspects raised by the authors include a set of social, economic and environmental factors. Trade facilitation reforms are improving the export performance of these countries per capita. The impact of physical infrastructure and information and communication technologies is becoming increasingly important depending on the welfare of the country (Portugal-Perez & Wilson, 2012; Androniceanu, 2021). However, the growing imbalance between imports and exports in world trade may lower transport companies' productivity (Othman et al., 2020).

It should also be noted that many theorists, practitioners and analysts have investigated the problems of studying the factors that influence the country's macroeconomic indicators. For example, Sharko et al. (2019) argue that the calculation of a priori and a posteriori information and the value of entropy provides an opportunity to regulate the process of accumulation of the required amount of information in management decisions. Furthermore, the need to investigate the interrelation between trade indicators and railway transport activities, which contributes to their sustainable development and acquiring synergistic effect, was raised by Sun et al. (2019). The authors substantiated the use of the entropy method for determining the level of railway transport and trade development.

One should add that a number of authors have also investigated the impact of transport infrastructure on the macroeconomic indicators of the state, evaluating and forecasting such impacts at macro, meso and micro levels: the main direction of their research was to forecast the volumes of cargo without studying their structure (e.g. Gurnak et al., 2019). In turn, the study of Zhou and Hu (2017) examines the stability of a complex economic system on the example of railways in different parts of China at different stages of the production cycle. Dobrodey et al. (2018) propose a model of the application system which allows analysing of specific regional railway system development projects. It takes into account the strategic state priorities and goals and corporate objectives of sustainable development of railway companies. Shpak et al. (2021b) propose a model of multidimensional analysis of the structure of transport companies' services and the degree of customer satisfaction). The connection between transport infrastructure and regional economic growth based on a multidimensional analysis of transport infrastructure is analysed by Hong et al. (2011). And the impact of transport infrastructure on economic growth in India using a vector error correction model to determine the relevant causal relationships was studied by Pradhan and Bagchi (2013).

In general, there are different approaches to identifying, grouping and evaluating the main factors influencing export activities. In particular, Fernandes and Winters (2021) studied the influence of political factors (Brexit referendum) as a quasi-natural experiment to study the impact of exchange rate shocks and uncertainty on the prices and volumes of export traffic for Portuguese exporters. One should mention that by examining the problems of the impact of certain factors on exports, the researchers concluded that the combination of goods and services is closely linked to the level of export intensity (Aquilante & Vendrell-Herrero, 2021). Based on a study of six global management indicators as explanatory factors for exports and their components, Bah et al. (2021) have found that political stability, the rule of law, control of corruption, voice, and accountability have a positive effect on export performance. But of these, only voice and accountability have a positive effect on

Volume **12** | Issue **1** | 2023
https://doi.org/10.18267/j.cebr.312

commodity exports. The study conducted by the authors was large-scale for 45 countries of Sub-Saharan Africa over almost 25 years.

Analysis of the literature on approaches to optimisation of export activities has revealed that some authors analyse criteria for optimisation of the transportation process, whilst others study indicators of exports or export structure. Modelling in the field of freight transport based on optimisation approaches for improving the process of transporting export cargo and taking into account the specifics of regional factors is presented by Zhao et al. (2015). Other authors, e.g. Wei and Dong (2019), studied the problems of organisational optimisation of domestic exports based on "dry ports" in the interior of China using network scenarios built by applying a two-criterion model of mixed-integer programming. Furthermore, Zhang et al., 2016) used approaches to integer optimisation of export rail transportation using binary variables as indicators of management decisions on the structure of goods. And finally, there are also authors who study the influence of transport factors using the conditional Bayesian delay propagation model (e.g. Zhang et al., 2019).

The analysis conducted allows us to draw several conclusions: i) there is no doubt that the matter that is being analysed is complex and multidimensional; ii) the issue of optimisation structure of the export activities is a matter of analysis of a number of scholars; they analyse the said topic from different points of view, using different approaches; and iii) there is lack of the model that could serve as the effective structure for rail transport.

1.2 Structural and dynamic analysis of export freight transportation of Ukrainian railways

The railway industry is considered one of the main factors in ensuring the stability of economic systems (Loo & Comtois, 2016). Ukrainian railway transport belongs to the most important ones in Europe. One predicts even that its importance will increase in the future. The last years were not so good for the Ukrainian railway companies (mostly to the pandemic of Covid-19). The total volume of transported goods in 2020 decreased compared to the previous year by 2.4% and amounted to 305.5 million tons, and the total turnover decreased by 3.4% and amounted to 175,587.2 million tkm. In 2020, 113.0 million tons of cargo were transported for export, which accounted for almost 37% of total freight traffic. The volume of these shipments decreased compared to 2019 by 2.8 million tons (-2.5%). As for the export turnover indicator, it showed similar trends. The share of cargo turnover for export in 2020 amounted to more than 44% of the total cargo turnover. In 2020, it decreased compared to the previous year by 3017.00 million tkm (-3.7%).

It should be noted that over the 13 years under study, there have been significant changes in the structure of export cargo. Thus, the largest share (almost 30%) in the structure of exports in 2006 fell on ferrous metals, and iron and manganese ore was 17.8%. In 2018, the share of ferrous metals in exports fell to 15.23%, and the share of iron and manganese ore more than doubled to 34.76%. It is unlikely that such an export structure can be considered optimal because the share of raw materials in Ukrainian exports is growing significantly. This is evidence of inefficient management, as the opportunity to export value-added products instead of raw materials is lost.

In the structure of export traffic in the last years of the studied period, the first place is occupied by iron and manganese ore (from 18.84% in 2006 to 36.01% in 2015), the second – grain and grinding products (from 3.52% in 2007 to 26.89% in 2017), in third place – mineral materials (from 12.78% in 2016 to 23.95% in 2013), in fourth place – ferrous metals from 14, 8% in 2017 to 29.42% in 2006.

The main consumers of Ukrainian exports (according to transportation documents) are Switzerland, China, Poland, Belarus and Turkey. Due to the free trade zone with the European Union, exports of Ukrainian goods to these countries increased by 10%. Ukraine is currently in the top 10 largest exporters of agricultural products, in many positions in the top five. But Ukrainian exports are mostly raw materials. The share of high-tech exports is currently 5.5%.

About 59% of the ore mined in Ukraine is exported. A significant decrease in recent years has taken place in the direction of Ukrainian seaports, mainly to China, due to high competition among world suppliers. The main competitors of Ukrainian companies in the Chinese market are suppliers from Australia and Brazil.

In order to maintain their position, Ukrainian producers need to reduce production costs and offer raw materials with a higher percentage of iron content as the world market, including China, increases its focus on purchasing high-quality raw materials every year. In addition, due to inflated Ukrainian port fees compared to other ports, the logistical component of supplies of Ukrainian raw materials to Chinese ports is quite high, so domestic exporters are trying to replace China with more profitable markets by reorienting supplies to Western Europe. Thus, ore exports to Switzerland, Slovakia, Hungary, Austria and others increased.

It should be noted that the increase in rail traffic was positively affected by the ban on the movement of vehicles weighing more than 40 tons by road. 80% of the processed grain in the ports of Ukraine is transported by rail. During the period 2018, deliveries to Switzerland, which is the main destination country (according to transportation documents), increased.

The second place is occupied by the EU countries. The main volumes went to Germany, Latvia and the Netherlands. According to The Ministry for Development of Economy, Trade and Agriculture of Ukraine (2020), Ukraine is among the TOP 10 largest suppliers of agricultural products to the EU (8th place). From 01.10.2017, exports from Ukraine to the European Union of most types of agricultural products take place without the application of customs duties. One should add that the Asian market, which is growing demographically, remains promising for Ukrainian farmers.

The third place in the structure of export traffic was taken by the Ministry of Construction Materials. Ferrous metals took fourth place in the structure of export traffic. In 2017, exports of ferrous metals were the lowest in 20 years. The main reason for the decrease in the transportation of ferrous metals is the reduction of production due to the cessation of supplies across the line of contact within the Donetsk and Luhansk regions and the loss of metallurgical capacity of Alchevsk, Yenakiyevo, Makeyevka and Donetsk plants. Despite the favourable situation in the world metal markets (high world steel prices, which are at their highest level since September 2014), Ukrainian metallurgy is in critical condition and has fallen to the level of twenty years ago. Metallurgical goods were exported to about 100 countries near and far abroad. The main shipments took place to Italy, Turkey, Russia and

Volume **12** | Issue **1** | 2023
https://doi.org/10.18267/j.cebr.312

the United States. Exports to Egypt fell significantly 2.5 times compared to last year and to Turkey 1.5 times.

The fifth place in the structure of export cargoes is occupied by non-ferrous ore and sulfur raw materials, and the sixth place by forest cargoes. The decrease was due to a ban from January 1, 2017 (for a period of 10 years) on the export outside the customs territory of Ukraine in the mode of export of pine trees for the purpose of restoring the woodworking and furniture industries. Also, from November 1, 2015, the export of untreated timber of wood species was prohibited.

The conducted structural and dynamic analysis of export cargo transportation by types of cargo allowed us to identify the main causes of structural changes in exports and group them: 1) temporary loss of Ukraine part of the regions for which the main branch of specialisation is the metallurgical industry; 2) increasing competition in various industries in world markets; 3) the impact of scientific and technological progress on the volume and structure of traffic; 4) suboptimal structure of exports, as explained by the raw material orientation of the economy. The first three reasons we attribute to environmental factors, the impact of which is difficult to manage and predict. The study of the flow of the fourth group of reasons is the subject of this study.

2 Research methods

This study uses structural modelling of enterprise performance indicators, particularly the volume of export cargo by railways of Ukraine in kind and value units for 2006-2020. This avoided the impact of inflation and other price factors on the results of further calculations. To assess the degree of structural uncertainty in the export of goods by the railways of Ukraine, the potential of the entropy index was used. The presence of structural uncertainty is due to the interaction of the main components: the dynamics of the structure of cargo turnover of export cargo by railways of Ukraine, the dynamics of the structure of revenues from export cargo by railways of Ukraine, and the dynamics of export cargo by railways of Ukraine for this period. The conducted economic interpretation of the category "entropy" made it possible to calculate the relevant indicators that indicate imbalances in the structure of export transportation.

3 Research results and discussion

The study of the problem of ensuring the sustainable development of railway transport in the part of export cargo transportation envisaged the choice of a suitable mathematical apparatus for the further optimisation of such strategically important activity for the state. Therefore, we have taken into account the achievements of scholars who have been studying the application of the entropy method in economics. The following achievements one may mention among them: i) it is proposed to evaluate the state of the economic national system using the developed methodology for quantification of the level of the orderliness of a complex economic systems system (Parshyn, 2015); ii) structural modelling of the product portfolio of the enterprise as a multicriteria task of optimisation of a complex dynamic system using the entropy index is realised; iii) the features of emergence and evaluation of entropy that can arise in the production and economic activity of the enterprise are investigated (Deineha & Deineha, 2018); iv) entropy theory is applied to different

processes and systems; v) an algorithm for calculating the index of structural fluctuations (entropy) in the economy is proposed; and vi) characteristics that are inherent in the enterprise from the position of entropy are studied.

The term "entropy" is interpreted as the uncertainty through which there is realised disorder of the system and the incompleteness of information about the system (Budnikova, 2012). The entropy in the Shannon formula (Shannon, 1948) is an average characteristic – a mathematical expectation of the distribution of a random variable and it is used as a measure of information uncertainty. The entropy (H) and the amount the information obtained by removing the uncertainty (I) depends on the initial number of variants (N) and the a priori probabilities of realisation of each of them (P), i.e. H = F (N, P).

In this case, the entropy is calculated using the Shannon formula proposed in 1948 in the paper "The Mathematical Theory of Communication" (Shannon, 1948):

$$H(X) = -\sum_{i=1}^{n} p(x_i)\, log_b\, p\,(x_i) \quad (1)$$

The minus sign is used because the logarithm of numbers less than 1 is negative.

But as $-\,log\, a = log\frac{1}{a}$ the formula can be written as:

$$H(X) = \sum_{i=1}^{n} p(x_i)\, log_b \frac{1}{p(x_i)} \quad (2)$$

Let's use the following entropy interpretation for this research: entropy is a measure of the structural uncertainty of export cargo transportation by Ukrainian railways.

This structure is due to the following main components: the dynamics of turnover of export cargo transportations by railways of Ukraine, the dynamics of revenues from the export cargo transportations by railways of Ukraine, and the dynamics of volumes of transportations of export cargoes by railways of Ukraine.

Entropy is an indicator of the degree of disorder of the system, that is, a measure of chaos, so it must be as small as possible to ensure the requirement for sustainable development of railway transport enterprises.

It is necessary to use the mathematical programming apparatus to achieve optimal values of the structure of exports according to a certain system of indicators, which will provide a minimum value of entropy.

Formulation of the problem will look as follows:

$$Z_1(W_{1j}) \rightarrow min, \quad (3)$$

$$Z_2(W_{2j}) \rightarrow min, \quad (4)$$

$$Z_3(W_{3j}) \rightarrow min, \quad (5)$$

where Z_1 – entropy of the structure of cargo turnover of export cargo transportation by railways of Ukraine;

Z_2 – entropy of the structure of revenues from export cargo transportations;

Z_3 – entropy of the structure of volumes of export cargo transportations.

The "minimum of entropy of export structure" is the criterion for optimisation of this objective function.

The system of limitations for this task is as follows:

$$W1j_{1jmax_{1jmin}}, \quad (6)$$

$$W2j_{2jmax_{2jmin}}, \quad (7)$$

$$W3jmax_{3jmin}, \quad (8)$$

$$\sum_{j=1}^{18} W_{1j} = 1 \quad (9)$$

$$\sum_{j=1}^{18} W_{2j} = 1 \quad (10)$$

$$\sum_{j=1}^{18} W_{3j} = 1 \quad (11)$$

where W_{1j} – the average share of the j-th type of cargo in turnover of export cargo transportations by railways of Ukraine in researched period;

W_{2j} – average share of the j-th type of cargo in the structure of revenues from export cargo transportations in researched period;

W_{3j} – average share of the j-th type of cargo in the structure of volumes of export cargo transportations in researched period;

j – index of the type of cargo($j = \overline{1,18}$);

W_{1jmin} – minimum value of the j-th share of turnover of export cargo transportations by railways of Ukraine in researched period;

W_{2jmin} – minimum value of the j-th share in the structure of revenues from export cargo transportations in researched period;

W_{3jmin} – minimum value of the j-th share in the structure of volumes of export cargo transportations in researched period;

W_{1jmax} – maximum value of the j-th share of turnover of export cargo transportations by railways of Ukraine in researched period;

W_{2jmax} – maximum value of the j-th share in the structure of revenues from export cargo transportations in researched period;

W_{3jmin} – maximum value of the j-th share in the structure of volumes of export cargo transportations in the researched period.

The range (see formulas 6-8) indicates the probable limits of variation of share of j-th type of cargo by year.

In the restrictions, we made the assumption that the values of shares should be not less than the corresponding minimum value for the 12 studied years and not exceed their maximum value.

Let's solve the problem using Microsoft Excel 2010 Office (Solver tool).

The evolutionary search for a solution for non-smooth optimisation problems is chosen as the solution method. As a result of the optimisation, we obtained an optimised structure of export cargo transportation, which ensures the achievement of the optimisation criterion, which is presented in a systematic form in (Tab. 1). The blue highlighted elements characterise the negative deviations of the results after optimisation of the corresponding structure from indicators before optimisation. As one can see, such reductions in the structure are characteristic of the 3 studied indicators. Such values of the structure of export after optimisation should ensure the sustainability of the development of the railway industry. A graphical illustration of the results of the calculations (Fig. 1-3) allows us to establish the similarity of the optimised structure by the selected criteria.

Table 1 | The structure of cargo turnover, revenues from transportation, and volumes of export cargo transportation by railways of Ukraine before and after optimisation

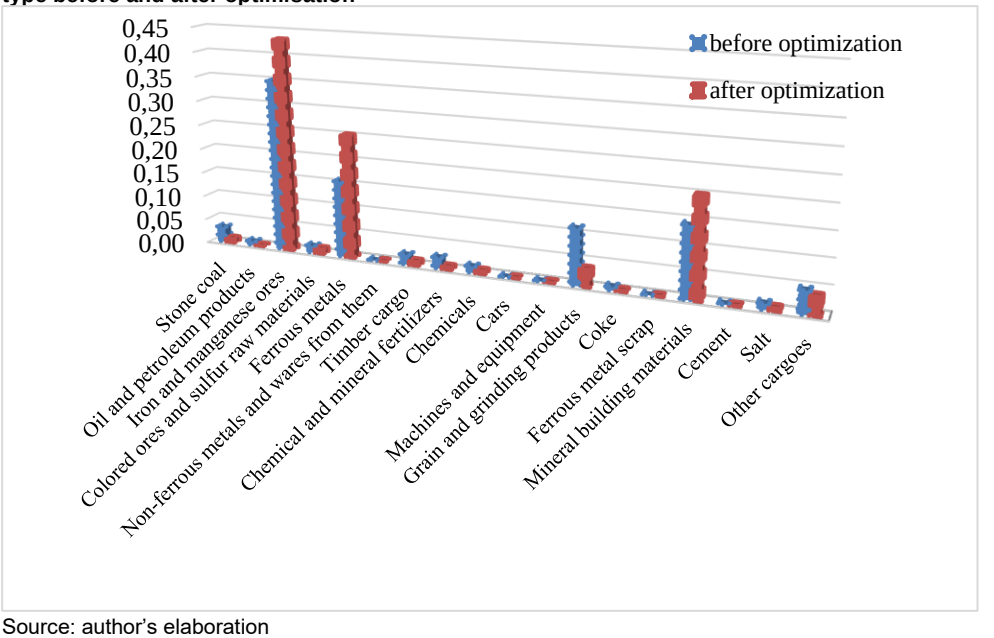
Name of cargo	The structure of turnover of export cargo transportation		Deviation	The structure of revenues from export cargo transportation		Deviation	The structure of volumes of export cargo transportation		Deviation
	before optimization	after optimization		before optimization	after optimization		before optimization	after optimization	
Total for kind of cargo	1.0000	1.0000	0.0000	1.0000	1.0000	0.0000	1.0000	1.0000	0.0000
Stone coal	0.0316	0.0082	-0.0234	0.0257	0.0050	-0.0207	0.0359	0.0044	-0.0316
Oil and petroleum products	0.0081	0.0007	-0.0074	0.0310	0.0014	-0.0296	0.0168	0.0006	-0.0162
Iron and manganese ores	0.3483	0.4317	0.0834	0.2260	0.2685	0.0425	0.2666	0.3601	0.0936
Colored ores and sulfur raw materials	0.0142	0.0096	-0.0046	0.0139	0.0100	-0.0039	0.0139	0.0121	-0.0018
Ferrous metals	0.1560	0.2508	0.0949	0.2405	0.2377	-0.0029	0.1946	0.2942	0.0997
Non-ferrous metals and wares from them	0.0001	0.0000	-0.0001	0.0004	0.0000	-0.0004	0.0002	0.0000	-0.0002
Timber cargo	0.0200	0.0081	-0.0119	0.0244	0.0095	-0.0149	0.0218	0.0098	-0.0121
Chemical and mineral fertilizers	0.0225	0.0055	-0.0171	0.0213	0.0043	-0.0170	0.0255	0.0053	-0.0203
Chemicals	0.0128	0.0059	-0.0070	0.0297	0.0121	-0.0176	0.0119	0.0046	-0.0073
Cars	0.0000	0.0000	0.0000	0.0003	0.0000	-0.0003	0.0001	0.0000	-0.0001
Machines and equipment	0.0008	0.0003	-0.0005	0.0053	0.0013	-0.0040	0.0012	0.0003	-0.0009

Volume **12** | Issue **1** | 2023
https://doi.org/10.18267/j.cebr.312

Grain and grinding products	0.1133	0.0353	-0.0780	0.1768	0.3057	0.1288	0.1469	0.0352	-0.1118
Coke	0.0070	0.0019	-0.0051	0.0126	0.0023	-0.0104	0.0088	0.0017	-0.0071
Ferrous metal scrap	0.0003	0.0000	-0.0006	0.0011	0.0001	-0.0010	0.0013	0.0000	-0.0013
Mineral building materials	0.1426	0.1977	0.0551	0.0881	0.0614	-0.0268	0.1953	0.2288	0.0335
Cement	0.0017	0.0006	-0.0011	0.0021	0.0005	-0.0016	0.0039	0.0009	-0.0029
Salt	0.0119	0.0057	-0.0062	0.0076	0.0032	-0.0044	0.0093	0.0036	-0.0057
Other cargoes	0.0458	0.0366	-0.0091	0.0930	0.0753	-0.0178	0.0461	0.0365	-0.0096

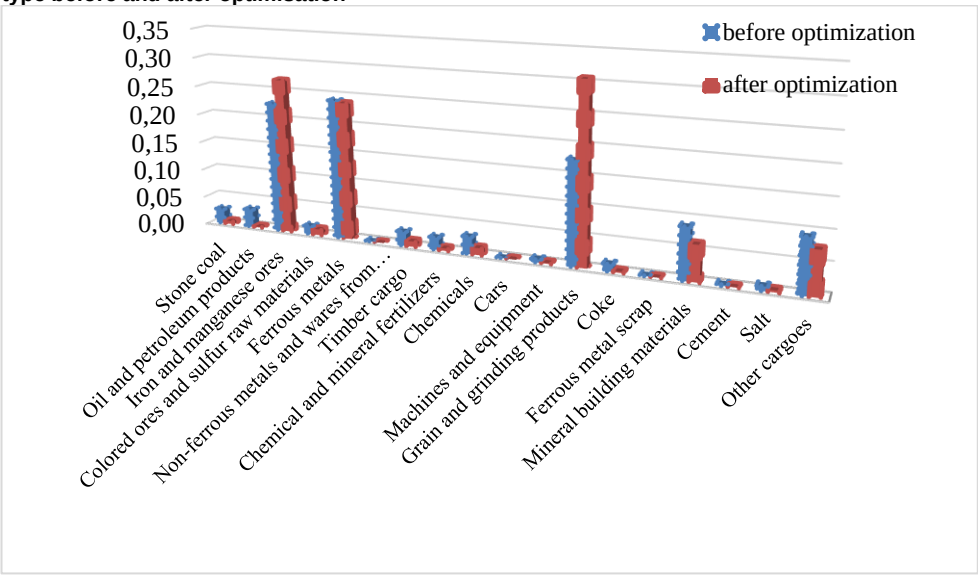
Source: author's elaboration

Figure 1 | The structure of turnover of export cargo transportation by Ukrainian railways by type before and after optimisation



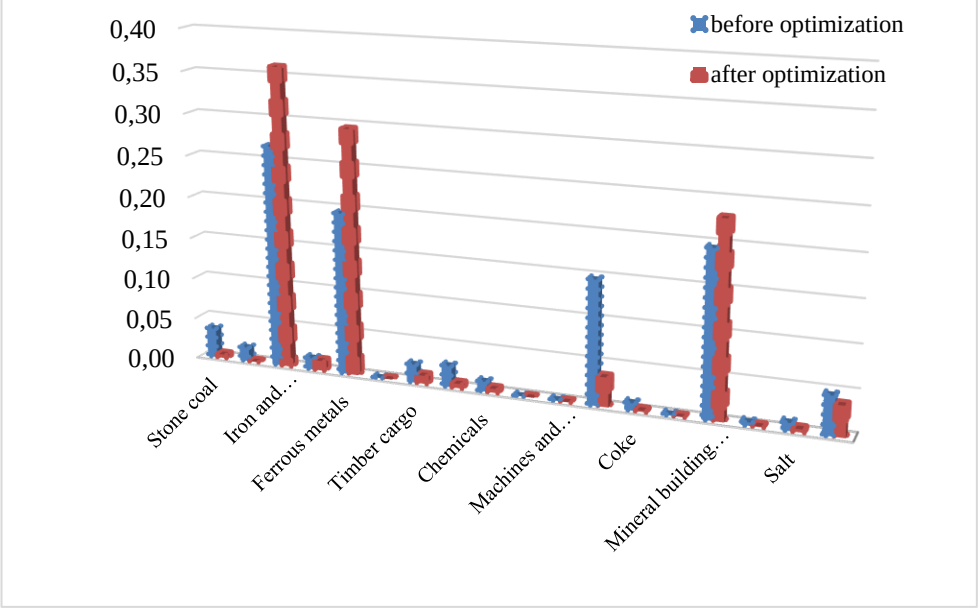
Source: author's elaboration

Figure 2 | The structure of revenues from export cargo transportation by Ukrainian railways by type before and after optimisation



Source: author's elaboration

Figure 2 | The structure of volumes of export cargo transportation by Ukrainian railways by type before and after optimisation



Source: author's elaboration

Therefore, according to the optimised structure, it would be advisable:

1) to reduce the values of cargo turnover, revenues from export cargo transportations and volumes of export cargo transportations for such cargoes – stone coal; oil and petroleum products; coloured ore and sulfur raw materials; non-ferrous metals and wares from them; timber cargo; chemical and mineral fertilisers; chemicals; machines and equipment; coke; ferrous metal scrap; cement; salt; other cargoes.
2) to increase indicators of cargo turnover, revenues from export cargo transportation and volumes of export cargo transportation for iron and manganese ores by 8.34%, 4.25% and 9.35%, respectively.
3) for the other 4 types of cargo (ferrous metals, cars, grain and grinding products, and mineral building materials), the optimised values of these 3 indicators had both positive and negative deviations. Therefore, for grain and grinding products, according to the optimisation model, it is recommended to reduce the volume of transportation and cargo turnover by 7.8% and 11.18% and to increase the revenues from the export of this type of cargo by 12.88%; for ferrous metals and mineral building materials, on the contrary, it is necessary to increase the volume of transportations and cargo turnover but to reduce the share of revenues from this type of transportations.

The results of the calculations were generated by the Solver tool in the form of a "Report on results". Provided that the structure is optimised for cargo turnover, revenues and volumes of transportation by type of cargo, a decrease in the entropy index is achieved as a requirement of sustainable development. The systematised calculated values of this indicator are presented in Tab. 2.

Table 2 | The calculated values of the entropy indicators

Indicators of entropy			Value	Deviation
Turnover of export cargo transportation	Z_1	before optimization	1.8579	-0.3538
		after optimization	1.5041	
Revenues from export cargo transportation	Z_2	before optimization	2.1050	-0.4338
		after optimization	1.6711	
Volumes of export cargo transportation	Z_3	before optimization	2.0166	-1.0186
		after optimization	0.9980	

Source: author's elaboration

As can be seen from Table 2, the largest reduction in the entropy indicator can be obtained by optimising the structure of volumes of export cargo transportation because this indicator has almost halved after optimisation. Therefore, this structure can be considered as a reference for further use in the analytical activity and in making appropriate management decisions at JSC "Ukrzaliznytsia".

As for the optimisation tools used by various scholars in the study of this problem, there were classical and adapted integer programming methods. This choice is due to the specificity of the proposed optimisation criteria, variables in the models – integers or binary variables that indicate the solution. In the studied models, the indicator of the export cargo transportation system state was not used as a criterion of optimisation to measure the balance of this system.

In contrast to the existing approaches to optimisation in the field of export transportation, we propose modelling based on a set of target functions with the criterion of optimisation – "minimum entropy", which allows for establishing the degree of balance of the system structure and the corresponding system of constraints. This model complex was practically implemented to optimise JSC "Ukrzaliznytsia" export freight while maintaining existing trends. Distinctive features of the study are: 1) the use of sectoral indicators (mesoeconomics level) for the transport sector (existing research in the field of entropy analysis, mainly focused on microeconomic or macroeconomic levels); 2) the potential of entropy analysis in the field of structural optimisation is revealed to a greater extent.

That's worth underlining that based on the sporadic phenomenon of Brexit, Fernandes and Winters (2021) stated that the shock of the referendum had a negative impact on Britain's export potential and reduced the likelihood of its growth. In contrast to this approach, our study presents the concept of a dynamic approach based on a more traditional scientific paradigm. This traditional approach is typical for many studies. In particular, the methodology presented by Zhang et al. (2016), which uses binary variables to achieve the criterion of optimisation of the maximum comprehensive preference of shippers to transport attributes, uses similar approaches to our study. However, we have chosen the minimum entropy as a criterion for optimisation to measure the disorder of the export structure system. In turn, the study of Dobrodey et al. (2018) proposed an imitation forecast of railway system operation in a macroregion using a similar scientific paradigm, which is based on a dynamic approach but without considering system status indicators. The results of our study differ in the entropic approach to identifying the state of the export structure of the transport company.

Conclusions

Our study showed the prospects for the application of optimisation of structures for scientific support of planning activities in transport companies. From the scientific point of view, our study made it possible to develop an algorithm for the structural modelling of enterprise performance indicators using entropy characteristics. One of the main stages of this algorithm is the structural and dynamic analysis of the object of study, which allows for identifying and systematising the main factors that affect the structure of export rail transport. The proposed algorithm of entropy analysis can serve as a value of imbalances in the structure of complex systems.

The result of the practical application of the proposed algorithm on the example of JSC "Ukrzaliznytsia" is an optimised structure of export freight. Eighteen names of cargoes transported by Ukrainian railways for export, according to optimisation calculations, have quite similar structures by year. However, the comparison of entropy values by three indicators (freight turnover, revenues, and volumes) allowed choosing the optimal export structure by volume. The entropy index double reduction of volumes (as an indicator of export structure imbalances) for the period under study can be obtained due to the optimisation of the structures of export cargo.

The results of the structural modelling are a reference point for the structure of transportation, which can serve as a basis for planning in the relevant field (railway infrastructure, volume, and quality indicators of transport work) for scientific support of the

Volume **12** | Issue **1** | 2023
https://doi.org/10.18267/j.cebr.312

railway transport of Ukraine. Also, the use of structural modelling will facilitate the adoption of such management decisions that trigger the mechanism of synergistic interaction of structural indicators of different economic entities. For further explorations, it is proposed to study the quantitative impact of the studied structure on the activities of the railway industry and the economy as a whole.

Limitations in such a study may be the presence of a significant statistical database for at least ten periods, during which the methodology of statistical data collection was comparable in time. It cannot serve as a benchmark for implementation but is used at the information analysis stage for decision-making. The obtained results of structural modelling have a recommendatory character and are not a variant of the final management decision on the structure of exports.

References

Androniceanu, A. (2021). Transparency in public administration as a challenge for a good democratic governance. *Administratie si Management Public*, 36, 149-164.

Aquilante, T., Vendrell-Herrero, F. (2021). Bundling and exporting: Evidence from German SMEs. *Journal of Business Research*, 132, 32-44. https://doi.org/10.1016/j.jbusres.2021.03.059.

Bah, M., Ondoa, H. A., & Kpognon, K. D. (2021). Effects of governance quality on exports in Sub-Saharan Africa. *International Economics,* 167, 1-14. https://doi.org/10.1016/j.inteco.2021.05.003.

Budnikova, Yu. V. (2012). Ентропія як економічна категорія [Entropy as an economic category]. Ефективна економіка, http://www.economy.nayka.com.ua/?op=1&z=1287

Deineha, O. V., & Deineha I. O. (2018). Ентропія в діяльності підприємства: суть та основні підходи до оцінювання [Entropy in the activity of the enterprise: the essence and basic approaches to evaluation]. Bulletin of the National University "Lviv Polytechnic", 892, 56-63. Retrieved November 10, 2021, from http://nbuv.gov.ua/UJRN/VNULPL_2018_892_10.

Dobrodey, V. V., Gitelman, L. D., Kozhevnikov, M. V., & Matushkina, N. A. (2018). Imitation forecast of railway system operation in a macroregion. *International Journal of Sustainable Development and Planning*, 13(5), 805-817. https://doi.org/10.2495/SDP-V13-N5-805-817.

Dvulit, Z., & Levchenko, O. (2017). Advanced vocational training of environmental professionals for providing sustainable development of railways of Ukraine on the way to European integration. *Baltic Journal of Economic Studies*, 3(5), 125–134. https://doi.org/10.30525/2256-0742/2017-3-5-125-134.

Fernandes, A. P., & Winters L. A. (2021). Exporters and shocks: Impact of the Brexit vote shock on bilateral exports to the UK. *Journal of International Economics*, 131, 103489. https://doi.org/10.1016/j.jinteco.2021.103489.

Gurnak, V., Volynets, L., & Khalatska, I. (2019). Intellectualisation of logistic supply chains on the basis of forecasting volumes of cargo transportation. In *MATEC Web of Conferences*, 294, EDP Sciences. https://doi.org/10.1051/matecconf/201929404013.

Hong, J., Chu, Z., & Wang, Q. (2011). Transport infrastructure and regional economic growth: Evidence from China. *Transportation*, 38, 737-752. https://doi.org/10.1007/s11116-011-9349-6.

Horská, E., Moroz, S., Poláková, Z., Nagyová, Ľ., & Paska, I. (2019). Evaluation of interaction between chosen indicators of development of regions in Ukraine. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 14(2), 341–357. https://doi.org/10.24136/eq.2019.016.

Joint Stock Company "Ukrzaliznytsia". (2019). Retrieved November 20, 2021, from http://www.uz.gov.ua.

Ključnikov, A., Civelek, M., Klimeš, C., & Farana, R. (2022). Export risk perceptions of SMEs in selected Visegrad countries. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 17(1), 173–190. https://doi.org/10.24136/eq.2022.007.

Kral, P., Janoskova, K., & Kliestik, T. (2018). Key determinants of the public transport user's satisfaction. *Administratie si Management Public*, 31, 36-51. https://doi.org/10.24818/amp/2018.31-03.

Kolarov, K., & Georgieva, S. (2020). Management features in Bulgarian SMEs as determinants of business internationalisation. *Polish Journal of Management Studies*, 22(1), 279-294. https://doi.org/10.17512/pjms.2020.22.1.18.

Le, H. (2022). Global economic sanctions and export survival: Evidence from cross-country data. *Entrepreneurial Business and Economics Review*, 10(1), 7-22. https://doi.org/10.15678/EBER.2022.100101.

Li, T. (2018). What Explains the Varying Degree of Export? Internal or External Factors. *Entrepreneurial Business and Economics Review*, 6(2), 29-43. https://doi.org/10.15678/EBER.2018.060202.

Loo, B. P. Y., & Comtois, C. (2016). Sustainable Railway Futures: Issues and Challenge. London: Routledge.

Meyer, D.F. (2021). A comparative analysis of the impact of merchandise exports versus services exports on economic growth for the SACU region. *Forum Scientiae Oeconomia*, 9(1), 5-23. https://doi.org/10.23762/FSO_VOL9_NO1_1.

Moldovan (Gavril), I.A. (2015). Does the Financial System Promote Sustainable Development? Evidence from Eastern European Countries. *Central European Business Review*, 4(2), 40-47. https://doi.org/10.18267/j.cebr.125.

Mindur, L., & Hajdul, M. (2013). The concept of organising transport and logistics processes, taking into account the economic, social and environmental aspects. *Transport Problems*, 8(4), 121-128

Ministry for Development of Economy, Trade and Agriculture of Ukraine. (2020). Retrieved December 5, 2021, from http://www.me.gov.ua.

Othman, M. K., Rahman, N. S. F. A., Ismail, A., & Saharuddin, A. H. (2020). Factors contributing to the imbalances of cargo flows in Malaysia large-scale minor ports using a fuzzy analytical hierarchy process (FAHP) approach. *The Asian Journal of Shipping and Logistics*, 36(3), 113-126. https://doi.org/10.1016/j.ajsl.2019.12.012.

Pancenko, E., & Ivanova, T. (2018). Evaluation of the export potential of Latvia with EU countries categorised by groups of goods. *Forum Scientiae Oeconomia*, 6(4), 37-50. https://doi.org/10.23762/FSO_VOL6_NO4_3.

Parshyn, Yu. I. (2015). Оцінка стану економічної системи національного господарства за показниками ентропії [Assessment of the state of the economic system of the national economy by the entropy indicators]. Держава та регіони. Серія: Економіка і підприємництво, 1, 16-20. http://www.econom.stateandregions.zp.ua/journal/2015/1_2015/5.pdf.

Petrová, M., Krügerová, M., Kozieł, M., & Štverková, H. (2021). Territorial risk management in relation to country risk classification and export. *Polish Journal of Management Studies*, 23(2), 369-385. https://doi.org/10.17512/pjms.2021.23.2.22

Portugal-Perez, A., & Wilson J.S. (2012). Export performance and trade facilitation reform: Hard and soft infrastructure. *World Development*, 40(7), 1295-1307. https://doi.org/10.1016/j.worlddev.2011.12.002.

Pradhan, R. P., & Bagchi, T. P. (2013). Effect of transportation infrastructure on economic growth in India: The VECM approach. Research in Transportation Economics, 38(1), 139-148. https://doi.org/10.34218/IJM.11.5.2020.081

Prokopenko, O., Kazanska, O., Deineha, I., Butenko, N., Omelyanenko, V., & Bovkun O. (2020a). Communication Business Processes of Industrial Enterprises in the Conditions of Globalisation. *International Journal of Management*, 11(5), 884-895. https://doi.org/10.34218/IJM.11.5.2020.081.

Prokopenko, O., Shmorgun, L., Kushniruk, V., Prokopenko, M., Slatvinska, M., & Huliaieva L. (2020b). Business process efficiency in a digital economy. *International Journal of Management*, 11(3), 122-132. https://doi.org/10.34218/IJM.11.3.2020.014.

Richter, S. (2015). Export Promotion Framework of the Czech Republic. *Central European Business Review,* 4(1), 37-49.

Shannon, C. (1948). A Mathematical Theory of Communication. Bell System. *Technical Journal*, 27(3), 379-423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x.

Sharko, M., Gusarina, N., & Petrushenko, N. (2019). Information-entropy model of making management decisions in the economic development of the enterprises. In International Scientific Conference “Intellectual Systems of Decision Making and Problem of Computational Intelligence” (pp. 304-314). Cham: Springer.

Shpak, N., Dvulit, Z., Luchnikova, T., & Sroka, W. (2018). Strategic development of cargo transit services: a case study analysis. *Engineering Management in Production and Services*, 10(4), 76-84. https://doi.org/10.2478/emj-2018-0024.

Shpak, N., Melnyk, O., Horbal, N., Ruda, M., & Sroka W. (2021a). Assessing the implementation of the circular economy in the EU countries. *Forum Scientiae Oeconomia*, 9(1), 25-39. https://doi.org/10.23762/FSO_VOL9_NO1_2.

Shpak, N., Mykytiuk, O., Dvulit, Z., Maznyk, L., & Horbal, N. (2021b). Simulation the attractiveness of transport services as a tool for assessing consumer loyalty in the digital epoch. CEUR Workshop Proceedings, 2870, 1500–1510. Retrieved December 5, 2021, from http://ceur-ws.org/Vol-2870/paper111.pdf

Стратегія розвитку ПАТ "Укрзалізниця" 2017-2021 року [Development strategy of PJSC "Ukrzaliznytsia" 2017-2021]. (2017). Retrieved December 3, 2021, from http://publications.chamber.ua/2017/Infrastructure/Session_4_Vasilevskiy.pdf.

Sun, Q., Wang, X., Ma, F., Han, Y., & Cheng. Q. (2019). Synergetic Effect and Spatial-Temporal Evolution of Railway Transportation in Sustainable Development of Trade: An Empirical Study Based on the Belt and Road. *Sustainability*, 11(6), 1721. https://doi.org/10.3390/su11061721.

Szczepaniak, I. (2018). Comparative advantages in Polish export to the European Union: food products vs selected groups of non-food products. *Oeconomia Copernicana*, 9(2), 287–308. https://doi.org/10.24136/oc.2018.015.

Wei, H., & Dong, M. (2019). Import-export freight organisation and optimisation in the dry-port-based cross-border logistics network under the Belt and Road Initiative. *Computers & Industrial Engineering*, 130, 472-484. https://doi.org/10.1016/j.cie.2019.03.007.

World Economic Forum (2019). The Global Competitiveness Report 2019. Retrieved November 10, 2021, from http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf.

Zhang, Y., Li, R., Guo, T., Li, Z., Wang, Y., & Chen, F. (2019). A conditional Bayesian delay propagation model for large-scale railway traffic networks. *Australasian Transport Research Forum*. Retrieved December 15, 2021, from https://www.australasiantransportresearchforum.org.au/papers/2019.

Zhang, Y.Z., Wang, J.Q., & Hu, Z.A. (2016). Optimisation Model of Transportation Product Selection for Railway Express Freight. *Journal of Engineering Science and Technology Review,* 9(5), 104-https://doi.org/10.25103/jestr.095.16.

Zhao, Y., Yang, Z., & Haralambides, H. (2015). Optimising the transport of export containers along China's coronary artery: The Yangtze River. *Journal of Transport Geography*, 77, 11-25. https://doi.org/10.1016/j.jtrangeo.2019.04.005.

Zhou, H., & Hu, H. (2017). Sustainability Evaluation of Railways in China Using a Two-Stage Network DEA Model with Undesirable Outputs and Shared Resources. *Sustainability*, 9(1), 150. https://doi: https://doi.org/10.3390/su9010150.

The research article passed the review process. | Received: January 31, 2022**; Revised:** April 20, 2022**; Accepted:** May 16, 2022**; Published online:** July 29, 2022**; Published in the regular issue:** March 20, 2023.