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THE SAFETY AND EFFICIENCY OF WATER TRANSPORT: STATISTICAL ANALYSIS

Summary. This paper provides comprehensive research on the linearity between the efficiency and safety of inland waterway transport (IWT). For this purpose, methods of statistical analysis are used. The efficiency of IWT is expressed by the transportation outputs, which today are strongly affected by the COVID-19 pandemic. This paper aims to find whether the demand for IWT has an impact on the accident occurrence probability.

The results show the linearity between shipping accidents and the outputs of freight and passenger IWT. The COVID-19 crisis has a higher impact on the efficiency of passenger navigation than on freight navigation. With reduced demand, the level of safety is higher but at the cost of declining efficiency in the transport sector.

1. INTRODUCTION

Water transport is considered to be the most environmentally friendly and effective mode of transport (regarding a specific energy use). Furthermore, modern high-capacity vessels are used, allowing one tonne of freight to be transported almost four times further than a lorry consuming the same amount of energy. Moreover, all these vessels and port handling equipment can use ecologically acceptable fuels, such as biodiesel and its blends [1]. Today, economists agree on the fact that water transport is the cheapest mode of transport. Therefore, in all European and European Union (EU) countries, the possibilities of using the existing waterway network are seriously considered. The analysis of water infrastructure shows that there is a very well-developed network of waterways in Europe, which are only partially used [2]. Approximately 30,000 kilometres of rivers and canals cross Europe, and European rivers flow through the continent's largest and most developed cities. Despite the favourable natural conditions in EU countries, water transport represents only 5.6% of total land transport in these hinterland countries [2].

The Danube, which is the world's most international river, directly connects several nations. The Danube is the longest waterway in the EU and the continent's second-longest river (after the Volga). The Danube, with its many tributaries and canals, connects the North and Black Seas and, thus, covers a massive part of Europe [3]. The Danube waterway may serve as the backbone of this region and ensure improved transport connections and economic growth [4].

In addition to the significance of the river Danube in the region, this waterway's flow is crucial to all of Europe. The Danube has multiple significant characteristics for the development and economy of the region. Furthermore, the Danube represents the cheapest and most ecologically acceptable transport mode. This fact is crucial considering that the Danube flows through highly developed countries (and creates connections between them), thus constantly increasing their levels of foreign

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trade and logistics services. This requires the sustainability of transport outcomes, high efficiency and the high quality of transport services.

However, the efficiency and sustainability of water transport are jeopardised by meteorological and hydrological conditions, such as weather, water levels and bottlenecks. Two years ago, a new threat started to affect the smooth and effective inland navigation, namely the COVID-19 crisis. Since the beginning of 2020, the world has undergone an unprecedented wave of preventive measures and lockdowns due to the COVID-19 crisis. The most harmful consequence of this crisis is evident in the field of tourism and transport, especially in passenger transport. The impact of the pandemic on the inland waterway transport (IWT) is expected to remain long after the COVID-19 pandemic comes to an end. Measures introduced to increase safety and health have essentially halted passenger shipping and tourism in the EU. Danube passenger transport has virtually come to a standstill. However, current cargo volumes could be well maintained at normal seasonal levels for now. Several lockdown periods have caused economies to slow down and will continue to heavily affect transport on the Danube in the coming months and years.

When compared with the effects of the financial crisis in 2009, a possible reduction in the volume of freight transport of at least 20% was estimated [5]. To date, four consequences of the COVID-19 pandemic specifically related to Danube navigation have occurred:

1. A drop in freight volumes due to a significant fall in demand.
2. A reduction in freight volumes as a result of decreased (or, in some cases, stopped) industrial production.
3. A dramatic disruption of cargo flows in order to entry bans, border checks and a lack of crew members.
4. A serious decrease in the number of passengers transported due to the standstill in the tourist sector [6, 7].

Some segments of transport were immediately and drastically affected by the COVID-19 crisis, mainly in terms of day trips, river cruises and ferry services. The crisis had a rapid impact on freight transport segments, especially in sectors directly influenced by lockdown regulations, such as the automotive industry, mobility sectors and construction. Other segments, such as the transportation of liquid cargo or containers, were delayed. Some sectors essential for the survival of the economy resisted the COVID-19 crisis better than others, but the data differ from one region to another.

In May 2020, the volumes of cargo transported on the Danube River stabilised and have remained at low levels. The economic situation of the IWT sector is still tense. However, the COVID-19 pandemic is not the only cause of the water transport output declines. Other causal factors are structural changes and seasonable effects in the energy sector. For the entire shipping industry (including logistics, passenger and freight transport and cargo handling), the financial losses heavily depend on the intensity and length of the crisis. Throughput and turnover losses could be 2.2 to 4.4 billion euros for passenger and freight transport, according to calculations [6, 7].

As mentioned, the efficiency of water transport lies in the high capacity of passengers and freight transported per kilometre. The idea of "safety first" is common, but the phrase "efficiency first" is a new important idea that has arisen from the pandemic. Sustaining efficient and safe water transport is a massive challenge, especially in periods in which measures are not very strict.

This paper provides an analysis of transportation outputs (both passenger and freight IWT) for the past 5.5 years, taking into consideration the changes that occurred because of the pandemic. Also, this paper contains an investigation of shipping accidents that occurred on the Danube River over the past several years. The linearity between the transportation outputs and shipping accidents (efficiency and safety) will be examined and revealed using various methods (analysis, synthesis, correlation and regression).

In the case of reduced demand, the level of safety has increased but at the cost of declining efficiency in the transport sector. It is evident that COVID-19 has had significant impacts on Danube navigation, as well as its effectiveness and safety.

2. LITERATURE REVIEW

This article contributes to the existing scientific literature from two perspectives. Firstly, the impact of the COVID-19 pandemic on the water transport sector is revealed, highlighting the vulnerable subsectors. Secondly, factors influencing safe and efficient Danube navigation are identified.

Several studies have overviewed the impact of COVID-19 on the output of the water transport sector. Mako and Dávid (2020) examined the effect of the COVID-19 pandemic on the maritime sector [8]. Shortall, Mouter and Van Wee (2021) proposed a classification of COVID-19 measures aimed at passenger mobility [9]. Cui et al. (2021) dealt with the impacts of the COVID-19 pandemic on China's transport sectors. In their research, the The Goddard Cumulus Ensemble (GCE) model and a decomposition analysis approach are used [10]. Borca and Putz (2021) provided initial insights into the impacts of the COVID-19 crisis on inland navigation on freight and passenger transport [11].

The topic of sustainable and safe inland navigation has been examined in many studies. Barsan et al. (2007) presented technical problems that must be solved in the Danube's bottlenecks in order to increase the safety of navigation [12]. Mihic, Golusin and Mihajlovic (2011) analysed data for the use of the Danube and provided an overview of measures used for efficient management, ensuring the long-term sustainable development of transport on the Danube [3]. Bjelajac, Pocuca and Mijatovic (2013) analysed the synergism in the theoretical sense, the practical application of legislation and the current condition in the field of industrial accidents on the basis of exact parameters (and particularly on the basis of the case study 'Accident on the middle section of the Danube River') [13]. Tarasenko, Zalozh and Maksymov (2018) utilised a model for managing environmental performance and energy efficiency of a self-propelled river towing and traction fleet [14]. Differences in maritime and inland technologies (including the Danube River) were shown in a study by Mako et al. (2021). The study also applied sustainable transport capacity models in order to increase the level of environmental performance and sustainability of IWT [15].

3. MATERIALS AND METHODS

The present research focuses on examining and evaluating the relationship between the two monitored statistical features (transportation outputs and the number of shipping accidents). The aim of this research is to determine the essence of the observed phenomena and, thus, an approach to so-called causal links. A causal link between two phenomena is a situation where the existence of a certain phenomenon is related to (results in or causes) the existence of another phenomenon. In this case, it is represented by the data about transportation outputs of IWT (both freight and passenger) and the occurrence of shipping accidents on the Danube River.

Regression and correlation analyses were used for the cognition and mathematical descriptions of statistical dependencies. For these methods, it is appropriate to distinguish between one-sided and interdependencies. A regression analysis deals with one-sided dependencies. This is a situation where an explanatory (independent) variable in the role of "causes" and an explanatory (dependent) variable in the role of consequences conflict with each other. The present study aims to answer questions about the form of change (e.g. explanatory variables y for changes explaining variables x). A correlation analysis deals with mutual (mostly linear) dependencies. In a correlation analysis, more emphasis is placed on the intensity of the relationship than on the quantities in the cause-effect direction. However, from the computational and interpretative points of view, there is a significant overlap between the two approaches.

Regression and correlation analyses aim to recognise and evaluate causal relationships between statistical features. The starting point for describing statistical dependencies is the collection of statistical data. The statistical set of n-observations of the observed statistical features can be obtained in different ways. For the purposes of elaborating this article, n statistical units were obtained by observing the spatially, temporally and materially defined statistical set (i.e. spatial statistical units are the number of vessels (cargo and passenger) within the Danube, and the temporal unit is the monitoring interval).

The main objective of this research was to find the mathematical function that best expresses the nature of the dependence and to show as faithfully as possible the course of changes in the conditioned averages of the dependent variables. This (essentially hypothetical) mathematical function is called the *regression function*. The main goal of regression analysis is to bring the empirical regression function as close as possible to the hypothetical regression function. In the case of the regression function, it is important to examine its dependence and intensity. Dependence is usually realised by capturing the given dependence with a certain balancing analytical function. For these regression functions, we chose some known functions from mathematics. Based on the regression function, the average values of the dependent variable can be estimated at the selected values of the independent variables [17]. The regression function fully corresponds to the data from which it was constructed. If the values of an independent variable other than those used in estimating the regression function are chosen, the estimates of y may not be correct.

In the case of strong dependence, the variability of the conditional distributions in relation to the total variability of the dependent variable will be relatively low. Estimates based on the regression function will be better the smaller the differences between the actual values of y and the balanced values of Y_i (for each i = 1, 2, ... n) are [16]. Thus, the intensity (correlation) of the dependence expresses the strength of the relationship between the variables (regardless of the course of the dependence) on the one hand and evaluates the strength of the dependence with respect to the estimated regression function on the other hand. It is necessary to distinguish precisely whether it is a force of dependence or dependence, the strength of which is conditioned by the quality of the regression function characterising the course of dependence. If an inappropriate regression function is used, the force of the dependence may appear to be small even if it is not realistic. Caution should be exercised even when there are few observations and when the regression function appears to be very good because the deviations between y_i and Y_i are small, and the dependence of the dependence has not been estimated. Rather, it has only been adapted by a certain analytical function to a small number of observations. In such cases, it is not possible to speak of the strength of dependence because the explanatory power of the regression function itself is insufficient [16, 17].

The empirical choice represents the basis for deciding on a suitable type of regression function. This is based on the analysis of the empirical course of addiction. The graphical method is a basic method, shows the dependence in the form of the above-mentioned scatter plot. In this plot, each pair of observations x and y forms one point. According to the characteristic course of the scatter plot, it is possible to decide which type of a particular regression function (e.g. line, parabola, logarithmic function) would be most suitable for the description of the observed dependence [16, 17]. Mathematical-statistical criteria are available to evaluate the quality of the obtained regression function and possibly to assess the validity of some assumptions related to the application of the used estimation methods. There is a theoretical (hypothetical) regression function that is unobservable (immeasurable) and an empirical (selection) regression function that is calculated based on empirical data. The empirical regression function can be considered as an estimate of the theoretical regression function. If the theoretical regression function is considered as a model of the course of the variable y with systematic changes in the explanatory variable x, then the empirical regression function is considered as an estimate of the model on the basis of obtained (selection) observations [17]. If the theoretical regression function is denoted as η_i, then the equation will apply to each observation:

$$y_i = \eta_i + \varepsilon_i \tag{1}$$

where y_i is the i-th value of the explained variable y_i, η_i is the i-th value of the theoretical regression function and ε_i is the deviation of y_i from η_i. The deviation ε_i occurs because the variable y is affected by variables other than the considered explanatory variable x because the form of the hypothetical regression function is not an accurate picture of immeasurable dependence and because random errors influence empirical observations. By its nature, ε_i is a random variable. It is advantageous to assume that ε_i does not distort the values of y_i in a systematic manner and that its mean value is zero [17]. We denote the parameters (unknown constants) of the regression function as β_0, β_1, ... β_p. Therefore,

$$\eta_i = f(x_i;\ \beta_0, \beta_1, \ldots \beta_p) \tag{2}$$

The main goal is to determine the specific form of the function and estimate its parameters. If the estimates of the mentioned parameters are denoted as b_o, b_1, ... b_p, then the empirical regression function can take the following form:

$$Y_i = f(x_i;\ b_0, b_1, \ldots b_p) \tag{3}$$

The quantity Y_i expresses that the i-th value of the empirical regression function is also an estimate of the theoretical value η_i, which corresponds to the value of the explanatory variable x_i. In the absence of error ε_i (for each i), the function η represents a rule that confidently assigns the value of the variable y to the value of the variable x. This would be a case of a fixed dependence, where the theoretical regression function holds with a probability equal to 1. Such a model is called a *deterministic model*. The deviations ε_i are the result of the action of all unconsidered factors that affect changes in the variable y. Since their number is practically infinite, this immeasurable ε_i is considered a random variable. A model containing random variables ε_i is called a *stochastic model*. The regression lines that capture a given dependence can be infinitely large depending on the value of the parameters. Determining the empirical regression function essentially means that each empirical value of y_i is replaced by a certain balanced value (Y_i), which lies somewhere on the regression line [17]. Therefore, it is necessary to find an objective criterion that allows the line that best describes the dependence to be determined. The first condition is that the positive and negative deviations of the empirical values from the balanced values are compensated. That is,

$$\sum_{i=1}^{n}(y_i - Y_i) = \sum_{i=1}^{n} e_i = 0 \tag{4}$$

where e_i (residue) is an estimate of the value of the random component ε. However, this condition does not yet lead to an unambiguous solution because there are an infinite number of regression functions that satisfy the above condition [8]. The condition $\sum e_i = 0$ must be supplemented by a criterion that provides a clear solution. Such a criterion is the requirement to minimise the sum of the square's errors ε_i before applying the following equation:

$$Q = \sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n}((y_i - \eta_i)^2 \ldots min \tag{5}$$

The sum of the squares of the deviations of the empirical values y_i of the dependent variable from the values of the theoretical η_i must be minimal [17]. The method of determining the parameters of regression functions based on this condition is called the least squares method.

4. RESULTS

The potential relationship between the number of vessels carrying passengers and cargo on the Danube River and the number of shipping accidents is examined in this section. For this purpose, methods of correlation and regression analysis are used. The least squares method is used to determine how the amount of cargo transported affects the probability of an accident.

4.1. Linearity between the number of passengers transported and shipping accidents

In the following section, the dependence between the number of passenger vessels (passenger cabin ships) passing through the Slovak section of the Danube and the number of accidents in the same section of the river is examined. The input data on the number of vessels transporting passengers on the Slovak part of the Danube from 2015 to 2020 are provided by the Bratislava Transport Authority [18] (Tab. 1).

The database involves data about cargo and passenger vessels for the past six years (Tab. 2). The data used for analysis contains paired variables representing the statistical features of the relationship between the transportation outputs and the number of shipping accidents. The least squares method is used to determine how the movement of passenger vessels affects the probability of an accident.

Table 1

Data about the number of passenger vessels travelling through the Slovak part of the Danube River

Year (quarters)	Number of passenger vessels
2015 Q1-Q2	1,376
2015 Q3-Q4	2,187
2016 Q1-Q2	1,516
2016 Q3-Q4	2,619
2017 Q1-Q2	1,585
2017 Q3-Q4	2,379
2018 Q1-Q2	1,763
2018 Q3 Q4	2,031
2019 Q1-Q2	1,901
2019 Q3-Q4	3,187
2020 Q1-Q2	60
2020 Q3-Q4	534

Source: [18].

Based on the input data, the interdependence of the two variables (transportation output and accidents) was evaluated. The dependent variable Y represents the number of shipping accidents, and the independent variable X represents the number of passenger vessels passing through the Slovak section of the Danube River for the purpose of transporting passengers. The data show that a change in the passenger transportation outputs causes a change in the number of shipping accidents (a greater number of cruise vessels is correlated with more accidents).

Table 2

Data on shipping accidents according to vessel type

Year	Number of accidents	
(quarters)	Cargo vessel	Passenger vessel
2015 Q1-Q2	3	3
2015 Q3-Q4	1	7
2016 Q1-Q2	5	5
2016 Q3-Q4	5	8
2017 Q1-Q2	11	7
2017 Q3-Q4	4	3
2018 Q1-Q2	4	5
2018 Q3 Q4	4	1
2019 Q1-Q2	2	5
2019 Q3-Q4	3	13
2020 Q1-Q2	3	1
2020 Q3-Q4	2	2

Source: [18].

Tab. 3 presents the output of regression analysis showing different variables (these are explained in detail in the paragraphs following the table).

Table 3

Regression analysis of passenger inland navigation

Regression Statistics	
Multiple R	0,723380267
R Square	0,523279011
Adjusted R Square	0,475606912
Standard Error	2,48945232
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	68,02627145	68,02627145	10,97663043	0,0078382
Residual	10	61,97372855	6,197372855		
Total	11	130			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0,11627502	1,703283599	-0,068265212	0,946920214	-3,9114274	3,6788773
X Variable 1	0,002904499	0,000876671	3,313099821	0,007838202	0,00095115	0,0048578

The multiple R coefficient represents the coefficient of correlation. The closer this value is to 1, the stronger the dependence is. The analysis yielded a multiple R coefficient of 0.72, indicating a very high degree of correlation between the number of passenger vessels and the number of shipping accidents. The R-square value (0.523) represents the value of the coefficient of determination. After being multiplied by 100, this value indicates that the chosen regression line shows the variability of the number of accidents is approximately 53%. The adjusted R-square parameter also considers the number of estimated parameters and the number of measurements. The standard error should be as low as possible [11]. The analysis of the dependence between the demand for IWT and the number of shipping accidents was carried out over a period of six years (2015 to 2020), considering the sum of the quarters (Q1 + Q2; Q3 + Q4), expressed as the value of observations.

In the ANOVA section, we tested the null hypothesis, stating that the model we chose to explain the dependence (in our case, a linear regression line highlighted in red) is not suitable (the alternative hypothesis states the opposite). The value derived from the F-test is 10.98. This value must be higher than the value of Ftab (Significance F), which is 0.008. This statement implies that the regression model is statistically significant. The Significance F value of 0.008 must also be lower than the value of "a" (i.e. the significance level), which is 0.05.

Based on the analysis, we reject the null hypothesis (H0), which means that the correct model was chosen. A partial elaboration of statistical analysis can also be achieved by graphical analysis, specifically by means of a graph plotting the XY dependence, trend line, linear function and line equation. Figure 1 shows how demand for passenger IWT impacts the safety of Danube navigation. The left side of the chart represents the share of accidents of freight vessels in the total number of vessels shipped each year. The linear trend line is highlighted in red in the chart. The regression function is **y = 0,0003x + 0,002.** The variable b0 (i.e. the value of the intercept) shows that if demand for passenger IWT equals 0, the number of accidents would be 0.002. The variable x (b1) signifies that if the demand increases by 1,000 passenger-kilometres[3] (one unit of measure for this case), the total number of accidents will increase by 0.002.

[3] A passenger-kilometer is performed when a passenger is carried one kilometer

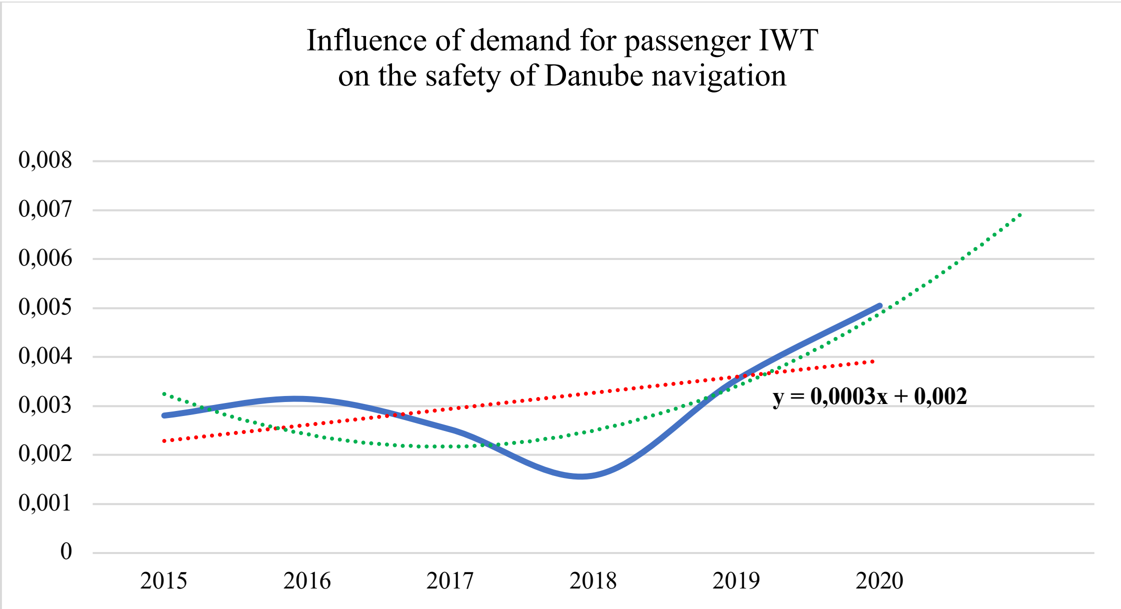

Fig. 1. Dependence between transportation outputs (passengers) and the safety of Danube navigation

A polynomial trend line (shown in green) shows a significant increase in shipping accidents over the next several years.

4.2. Linearity between the outputs of freight IWT and shipping accidents

The influence of demand for cargo IWT on the accidents on the Danube is examined using correlation and regression analysis. The research is based on two types of data. The first category consists of data for the number of vessels transporting cargo on the Slovak part of the Danube to and from the Slovak Republic from 2015 to 2020 (Tab. 4). The following types of vessels are involved:

- tanker vessels (ships designed to transport or store liquids or gases),
- pusher tugs (towboats designed for pushing barges),
- general cargo ships (ships that can carry packaged items, such as food, machinery, chemicals, motor and military vehicles and footwear).

Table 4

Number of cargo vessels shipping through the Slovak part of the Danube River

Year	Number of cargo vessels according to type		
(quarters)	**Tanker**	**Pusher Tug**	**Cargo Vessel**
2015 Q1-Q2	371	959	1487
2015 Q3-Q4	390	1038	1476
2016 Q1-Q2	361	1114	1560
2016 Q3-Q4	894	1122	1741
2017 Q1-Q2	442	1030	1269
2017 Q3-Q4	444	1320	1454
2018 Q1-Q2	505	1071	1286
2018 Q3 Q4	438	814	1252
2019 Q1-Q2	297	1104	1626
2019 Q3-Q4	323	985	1453
2020 Q1-Q2	303	958	1634
2020 Q3-Q4	304	904	1260

Source: [18].

Data on navigation accidents on the Slovak part of the Danube River (Tab. 2) are collected from 2015 to 2020 [10]. The database contains paired data for the statistical features of the relationship between the demand for freight IWT and the number of shipping accidents. The least squares method is used to determine how the amount of cargo transported through the Danube waterway affects the probability of an accident (Tab. 5).

Based on the input data regarding the demand for freight IWT and the number of shipping accidents, the interdependence of these two variables is evaluated. The number of cargo vessels passing through the Slovak part of the Danube represents the independent variable X, and the number of shipping accidents represents the dependent variable Y. In this case, we assume that a change in the demand for IWT would cause a change in the number of shipping accidents (increased demand would lead to more accidents). This expectation is the same as in the case of passenger IWT.

The multiple R (correlation coefficient) value is 0.827. As mentioned earlier, the closer this value is to 1, the stronger the dependence. In this case, there is a high degree of correlation between the demand for the IWT of cargo and the number of shipping accidents (higher than in the case of passenger IWT). The value of R-square (0.684) is the value of the coefficient of determination. After multiplying this value by 100, it can be seen that the variability of the number of accidents is about 70%. The remaining 30% represents the influence of random and unspecified factors.

The adjusted R-square variable also considers the number of estimated parameters and the number of measurements. The standard error should be as low as possible (in this case, it is less than 1). The dependence between the demand for IWT of cargo and the number of shipping accidents was analysed across six years, considering the sum of the quarters (Q1 + Q2; Q3 + Q4), expressed as the value of observations.

The null hypothesis is tested using an ANOVA in order to determine the model's accuracy. The value derived from the F-test is 21.63, which is higher than the Ftab value (0.00091). Therefore, we can state that the regression model is statistically significant. Also, since the value of Ftab is less than 0.05, we can also state that the level of significance is correct.

We reject the null hypothesis (H0), which means that the correct model was chosen. A partial elaboration of the regression and correlation analyses can also be given by considering various types of graphical analysis by means of a graph depicting the XY dependence, trend line, linear function and line equation. Fig. 2 shows the influence of the demand for freight water transport on the safety of Danube navigation. The left side of the chart represents the share of accidents of freight vessels in the total number of vessels shipped each year.

The linear trend line (the red line) shows the process of linearity between the IWT freight outputs and the number of accidents. The polynomial trend line (the green line) was chosen to forecast the number of shipping accidents and their relation to the increased amount of transported cargo. Even in the period in which the COVID-19 pandemic influenced the freight IWT and its outputs, the polynomial line continues to show an increase in the number of accidents.

The regression function takes the form **y = - 4E - 05x + 0,0015**. The value of the intercept (b0) says that if the demand for freight water transport is equal to 0, the number of accidents would be 0.0015. The value of X Variable 1 (b1 = 0.0015) states that if the amount of demand increases by 1,000 tonne-kilometres (one unit of measure in this case), the number of shipping accidents increases by 0.0015.

5. CONCLUSIONS

Inland waterway transport (IWT) has been significantly declining continuously since the beginning of the COVID-19 pandemic. Three main segments of IWT freight transport (liquid cargo, dry cargo and containers) are affected differently. Based on the data from Eurostat, CNNR and Danube Commission, the demand for IWT of passengers is very low [6, 7]. The amount of cargo transported on the Danube is not different from previous years. Despite the impact of the COVID-19 crisis, it is crucial to preserve the safety and efficiency of passenger and cargo IWT.

Table 5

Regression analysis for freight water transport

Regression Statistics						
Multiple R	0,826947301					
R Square	0,683841839					
Adjusted R Square	0,652226023					
Standard Error	0,973896546					
Observations	12					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	20,51525518	20,51525518	21,62973866	0,000906967	
Residual	10	9,484744824	0,948474482			
Total	11	30				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-7,74962783	2,541973557	-3,048665793	0,012279635	-13,4134979	-2,0857578
X Variable 1	0,00402971	0,000866459	4,650778285	0,000906967	0,002099119	0,0059603

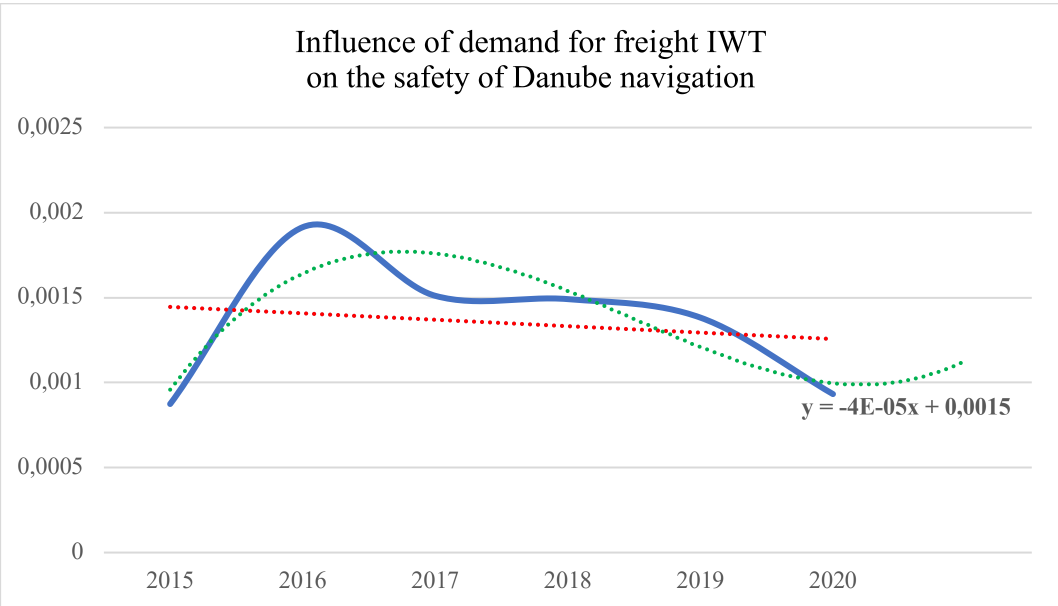

Fig. 2. Dependence between transportation outputs (freight) and the safety on Danube

The safety and efficiency of inland navigation are closely related. Research on the dependence between IWT demand and shipping accidents (efficiency vs safety), addressed by regression and correlation analysis, confirmed this dependence. Two types of data were used for the research – vessels (passenger and cargo) flow on the Danube River and the number of shipping accidents. We concentrated on the data from the Central Danube to the Slovak part of the Danube. This relationship and its dependence were investigated using regression and correlation analysis.

Regression analysis is a set of statistical methods used to study the interrelationships between two or more variables, the primary aim of which is to estimate the values or mean values of a dependent variable. Correlation analysis applies procedures for assessing the correlation and free statistical dependence between quantitative and various variables and for evaluating the quality of regression functions.

Based on the results, a change in the demand for transport services significantly affects the safety of navigation. In the case of reduced demand, the level of safety increased at the cost of declining efficiency in the transport sector. It is doubtless that the COVID-19 pandemic has significantly impacted Danube navigation, as well as its effectiveness and safety. Nevertheless, the crisis has had a negligible impact on freight transport. Shipping companies are rightly afraid of the effects of future waves of the epidemic. Companies are already considering long-term issues with transportation modes used together with supply chain dependencies [19]. Finally, in conclusion, we argue that the COVID-19 crisis is causing greater impacts on the efficiency of inland navigation of passengers than on freight inland navigation.

Based on predictions, it can be stated that when the COVID-19 crisis ends, the demand for water transport will return to the levels seen after the economic crisis in 2009 [20, 21]. Consequently, the threat of accidents will increase again, which will jeopardise the safety of shipping. As the ever-increasing demand for IWT (before the COVID-19 crisis) adversely affected the number of shipping accidents, it is important to take measures to prevent waterway accidents.

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