

Ginevičius, Romualdas; Sinkevičius, Gintaras

## Article

# Quantitative assessment of the dynamics of rail freight transportation

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# QUANTITATIVE ASSESSMENT OF THE DYNAMICS OF RAIL FREIGHT TRANSPORTATION

Romualdas Ginevičius<sup>1</sup> and Gintaras Sinkevičius<sup>2</sup>

<sup>1)</sup> Białystok University of Technology, Faculty of Management,  
Department of Business Informatics and Logistics, 15-351 Białystok, Poland.

<sup>2)</sup> Vilnius Gediminas Technical University, LT-10223 Vilnius, Lithuania.

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## Abstract

Freight transportation by rail is one of the most important factors in the country's economic development; and, therefore, a comprehensive analysis of the business development has both scientific and practical significance. The basis for the analysis and conclusion of this type is a possibility to measure the trends of transport development. They have been objectively reflected in the dynamics of transportation business during the given period. The dynamics has been reflected by two indicators: the level, and the intensity of the transportation operations. The consistency of transportation operations can be determined as the ratio between the size of the time span and the size of the trajectory of the actual development. Whereas the intensity of the shipment can be determined as the ratio between the amount of shipment at the end of the period as compared to the same value at the beginning of the period under consideration. The calculations have shown that there is a fairly strong link between GDP per capita for the country and the dynamics of rail freight transportation.

## Keywords

Railway transportation, international markets, dynamics of rail freight transportation, economics, internationalization, sustainable development, intensity of transportation, dynamics of transportation, uniformity of transportation.

**JEL Classification:** R1, R4, C6

<sup>1</sup> Corresponding author, **Romualdas Ginevičius** – [romualdas.ginevicius@vgtu.lt](mailto:romualdas.ginevicius@vgtu.lt)

## Introduction

Rail transportation (hereinafter referred to as “RT”) is one of the major economic drivers of the global and regional development (Christopher 2011; Granger & Kosmider 2016). This is an important element of the development of technology and international economic relations (Hays 2010; Siciliano *et al.* 2017). The business of rail transportation significantly influences the processes of globalization, and it is an integral part of internationalization processes (Granger & Kosmider 2016; Wang *et al.* 2018). Research of this problem has consistently highlighted the growing importance of RT over the recent time. In particular, it has grown on the basis of global and regional development through the adoption of the concept of sustainable development, which focuses on the ecological issues of human and economic development (WCED 1987).

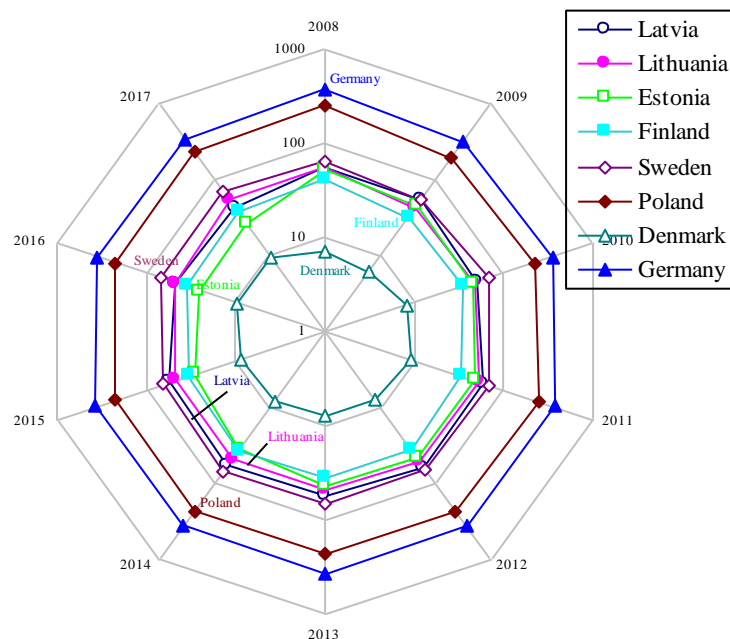
To start with, rail freight transportation has a direct impact not only on economic performance but also on processes, such as regional development, city urbanization, and alike. (Atack & Bateman 2006; Islam *et al.* 2013). It is an integral part of the interaction between the given economic activity and transport links (Wishniewski 2015). Owing to rail transportation, modern processes, such as globalization, technological progress, people’s mobility, and trade are developing (Gereffi & Fernandez-Stark 2011; Newman *et al.* 2017).

In the region of the Baltic Sea, freight transportation by rail accounts for about 40 per cent of all cargo flows (Ketels & Pedersen 2016). Their volumes largely depend on the geographic location of the country. The countries of the European Union, which are intercrossed by the international transport corridors are situated in a rather favorable position (Morana *et al.* 2014; Upadhyay & Bolia 2014; Summers 2016). These countries, whose territory is bordered by the Eurasian Economic Area, between 2014 and 2015, make 80-95 per cent of all international rail freight flows (Allesandrini *et al.* 2016; Gherghina *et al.* 2018). The dynamics of international trade and cargo transportation in the Baltic Sea area is analyzed by the relative distribution of transportation flows to the North-South and East-West directions (Baltic Sea ... 2014). Table 1 and Figure 1 show that freight transportation by rail has varied considerably between North-South and East-West. In the East-West direction freight flows are about ten times larger than in the North-South direction (Baltic Transport ... 2011). One of the reasons for this discrepancy is that northern export to the southern countries is almost at a twice higher volume than import (Li *et al.* 2017). Meanwhile, the eastern export to the West is much higher than the import.

**Table no. 1: The statistics for Freight rail transport  
for the Baltic Sea Region countries as of 2005-2017, thousand t.**

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Country	Freight quantity thous. t									
Latvia	56.061	53.679	49.164	59.385	60.601	55.831	57.039	55.645	47.819	43.785
Lithuania	54.970	42.669	48.061	52.330	49.377	48.028	49.000	48.053	47.651	52.638
Estonia	52.752	45.954	46.705	48.378	44.725	43.682	36.289	28.026	25.364	27.256
Finland	41.937	32.860	35.795	34.827	35.267	36.433	37.008	33.392	36.162	38.406
Sweden	65.632	56.466	68.329	67.907	65.789	67.047	68.035	64.999	67.479	69.350
Poland	248.860	200.819	216.767	248.606	230.878	232.596	227.820	224.320	222.523	233.982
Denmark	7.198	6.163	8.121	9.276	7.982	7.956	8.082	8.652	9.383	9.314
Germany	371.298	312.087	355.715	374.737	366.140	373.738	365.003	367.314	363.512	348.559

Source: EC 2019.



**Figure no. 1: Rail freight volumes in the Baltic Sea Region**

*Source: completed by the authors.*

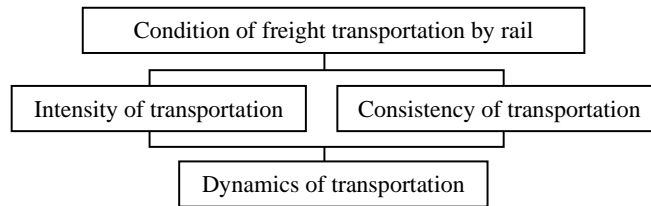
In 2014, the International Union of Railways (UIC) developed directions for strategic technical and technological development of European rail transportation, reflecting upon the priorities of the implementation of the RT policy. The priorities also emphasize the sustainable development alongside as consistency, security, reliability, financial efficiency and other components (UIC 2014). Concerning this context, the research on the effectiveness of RT has highlighted the following issues of its development: the lack of a critical approach to the development of rail transportation in modern business conditions; there is a lack of consistent analysis and forecasts of freight transportation by rail that allows targeted integration with other business types (Pitmann 2009; Ruijia *et al.* 2014). For these reasons, the GCC sector is losing out in a competitive struggle for cargo flows (Makitalo 2010; Steele & Hodge 2011). Modern approaches to the development of RT are needed, together with new research covering new aspects that have not yet been explored (Sinkevičius & Dailydka 2014).

Anyway, the basis for this kind of analysis, and research, is the possibility of quantifying the actual state of development of the RT. The objective of the article is to quantitatively evaluate the dynamics of rail freight transportation over the ten-year period in the countries of the Baltic Sea region, and to determine this impact on the country's economic development.

#### **Methodology for quantitative assessment of dynamics of rail freight transportation**

The country's railway system has all the characteristics of socioeconomic systems (SES). It is large, complex, and in reality it manifests itself in a large number of different aspects (Klapita 2012). It is an open system, so it is constantly exposed to the surrounding environment. This environment promotes the need for continuous growth. There is a need

to enable the system to adapt to the ever-changing external situation. This can only be achieved through continuous development (Alvarez *et al.* 2009; Chen 2012; Crozet 2017). Cargo transportation is an essential component of the national railway transportation. It is the business that has a major impact on the national economy (Ivaldi & McCullough 2010; Wang 2012; Cervantes 2013). It is, therefore, important for the science and practice to fully examine the conditions under which the success depends. The basis for such analysis is provided by the ability to quantify the actual status of development at the time point under consideration. The structure of freight transportation by rail can be reflected upon two essential aspects – the intensity of transportation and the consistency (Ginevičius *et al.* 2018). Their integral size is conveyed by the dynamics of transportation (Figure 2). The dynamics, as an indicator of the state of rail transportation, matters because it marks the evolution of any kind of process, evolution, and course of some kind of phenomenon.



**Figure no. 2: The structure of rail freight transportation**

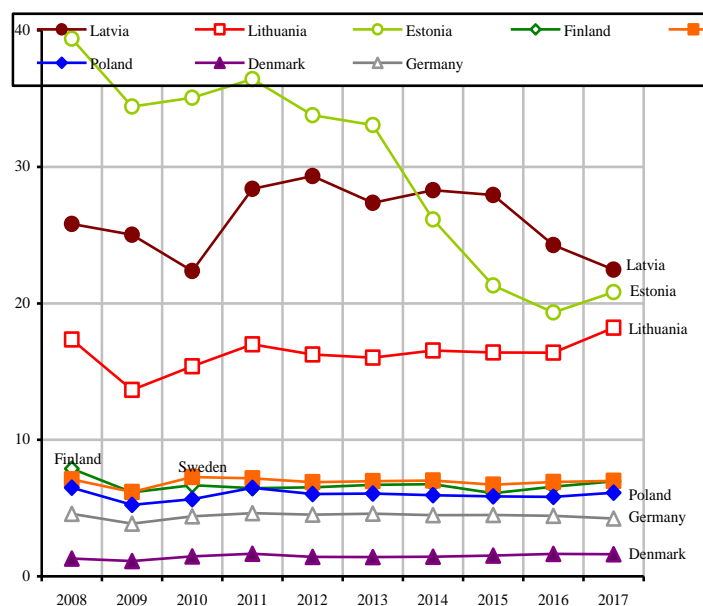
*Source: authored by Ginevičius et al. 2018.*

The process of dynamic is characterized by a rapid, tangible development (the European Commission. Eurostat Database ... 2019; the European Commission. The Eurostat statistics ... 2019). The rationale of the parameters of the dynamics – intensity and uniformity – can be confirmed (or denied) by the graphical representation of the actual freight transportation by rail. In order to adequately convey the situation of the countries concerned, the data should be comparable, as the countries differ in size, area, population, etc. This is illustrated by the relative sizes – the volume of freight transported per 100 km<sup>2</sup>, of the country, the volume of cargo per 1 000 of the country's population and so on. Which of these indicators should be taken as a basis for the future research can be reflected in their relationship with the economic development of the countries, which we can express by GDP per capita (Maibach *et al.* 2008; Liddle & Lung 2013). The correlation analysis has shown that it would prove to be meaningful to collect the amount of cargo transported per 1 000 inhabitants of the country. For the countries concerned, this indicator is presented in Table 2 and Figure 3, where these changes are graphically represented.

**Table no. 2: Rail freight volumes per 1 000 of the country's population**

	Country	Year									
		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	Latvia	25.822	25.025	22.367	28.386	29.332	27.368	28.293	27.934	24.273	22.465
2	Lithuania	17.351	13.662	15.389	16.995	16.258	16.025	16.548	16.394	16.386	18.213
3	Estonia	39.396	34.422	35.063	36.429	33.780	33.067	26.144	21.312	19.332	20.822
4	Finland	7.884	6.151	6.671	6.462	6.516	6.702	6.752	6.092	6.571	6.953
5	Sweden	7.106	6.181	7.276	7.174	6.896	6.973	7.021	6.708	6.911	6.997
6	Poland	6.493	5.240	5.656	6.487	6.025	6.071	5.949	5.862	5.821	6.129
7	Denmark	1.309	1.115	1.462	1.661	1.422	1.411	1.434	1.521	1.642	1.624
8	Germany	4.576	3.867	4.397	4.630	4.516	4.599	4.479	4.495	4.437	4.244

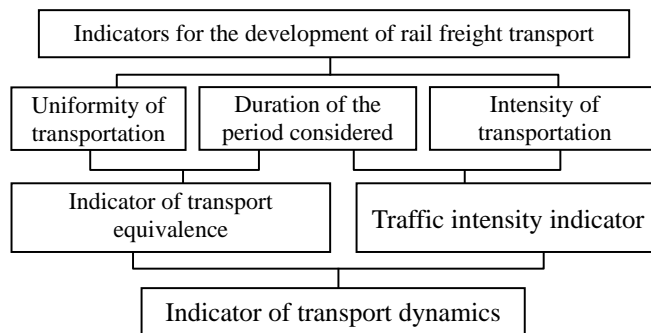
*Source: authors' compilation of rail freight statistics based on Eurostat.*



**Figure no. 3: Dynamics of rail freight transportation in the Baltic region in 2008-2017**

*Source: composed by the authors.*

Figure 3 shows that, in addition to the two parameters (intensity and uniformity), the duration of the period under consideration should be taken into account, in order to summarize the development of rail freight transportation. The first two parameters for each country will be different, e.g. the first two are variables, and the third one is constant. Figure 3 also shows that whereas transportation intensity increases, the uniformity decreases. Hence, in order to obtain an adequate view of the uniformity of transportation, the condition is that the value should not be affected by the intensity of the carriage. The intensity indicator should accordingly be integrated into the dynamics of transportation development. In this case, the system of indicators for the development of rail freight transportation can be demonstrated as depicted below (Figure 4).



**Figure no. 4: The system of indicators for the development of rail freight transportation**

*Source: composed by the authors.*

Combinations of variable parameters – intensity and uniformity – in the process of development of freight transport by rail transportation allow to distinguish typical situations (Figure 5).

		Rail freight intensity	
		Intensive	Non intensive
Uniformity of rail freight transportation	Uniform	Intensive and uniform (high degree of development dynamics)	Non intensive either uniform (average degree of development dynamics)
	Non-uniform	Intense, but uneven (average degree of development dynamics)	Intense and uneven (low dynamics of development)

**Figure no. 5: Typical cases of the development of rail freight transportation development**

*Source: composed by the authors.*

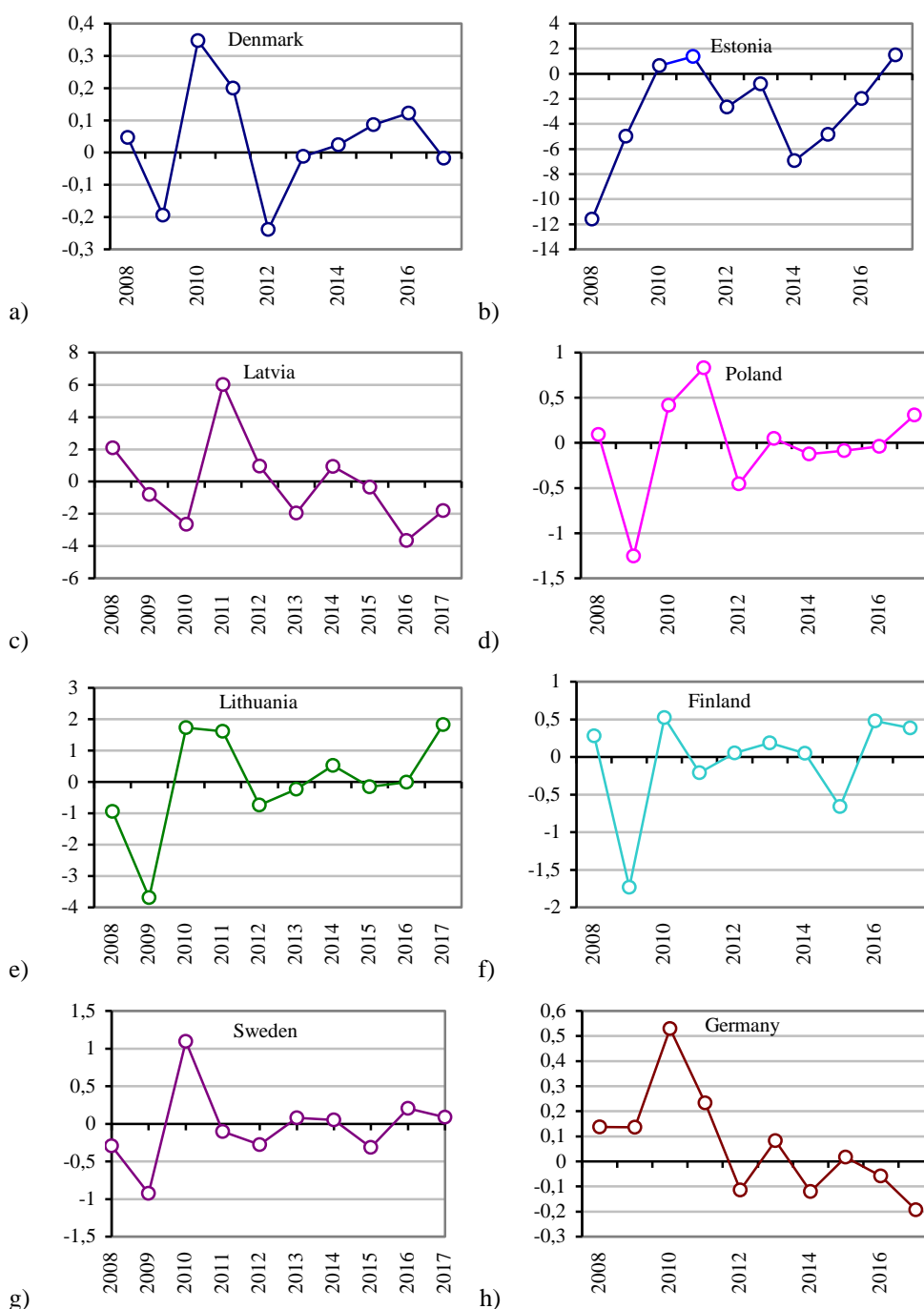
Based on Figure 5, the countries in consideration can be classified as quadrants (Figure 6):

		Rail freight transportation intensity	
		Intensive	Non intensive
Uniformity of rail freight transportation	Uniform	Estonia, Latvia, Lithuania	Denmark, Poland, Finland, Sweden, Germany
	Non-uniform	–	–

**Figure no. 6: The situation of rail freight in the countries concerned**

*Source: composed by the authors.*

The quantification of the transportation of goods by railways will be quantified on the basis of fluctuations in the volume of transportation during the particular periods of the period under review. This can be done on the basis of the difference in the development of transportation times of adjacent periods of time (Ginevičius *et al.* 2018). Figure 7 shows what the transformed Figure 3 depicts upon transformation. The graphs show the ascending and descending curves accordingly to the countries in question.



**Figure no. 7: Uniformity of rail freight transportation in the Baltic Sea region for 2009-2010: a) Denmark, b) Estonia, c) Latvia, d) Poland, e) Lithuania, f) Finland, g) Sweden, h) Germany**

*Source: authors' compilation of rail freight statistics based on Eurostat.*



The dynamics of rail freight transportation in the countries of the Baltic Sea Region will be determined based on the MDD method (Ginevičius *et al.* 2018). The essence of the method is that the uniformity of the development of the examined process is determined first, and then its value is adjusted by the indicator of intensity. The development equilibrium indicator, based on the methodology explained earlier, is calculated as the ratio of the size of a total duration of the analyzed period to a size of the tactical development trajectory. The actual length of the development trajectory is the sum of the growth rates for each time period in relation to the period in question. It is determined on the basis of Figure 7. Therefore, we now know the significance of the development at the beginning and end of each time period (Figure 8).

From Figure 9 one can notice that during the period under review, the trajectory of the development of transportation in the  $i$ -th period is reflected by the  $P_i$  and  $P_{i+1}$ , the diagonals of the right-angled triangle.

$$P_i P_{i+1} = \sqrt{1 + (P_{i+1} - P_i)^2}. \quad (1)$$

In this case, the total length of the actual trajectory for the period under consideration is determined as the sum of the lengths of the individual trajectory of the time, and the development equilibrium index  $D^T$  is as follows:

$$D^T = \frac{N-1}{\sum_{i=1}^{N-1} \sqrt{1 + (P_{i+1} - P_i)^2}}, \quad (2)$$

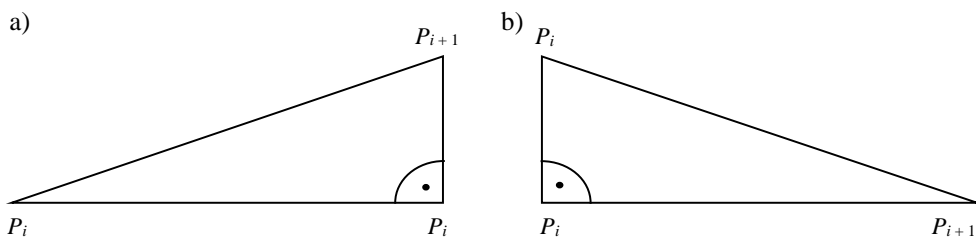
where:

- $N$  – period under consideration;
- $(N-1)$  – number of periods of considered duration by years.

The proposed methodology has been tested to determine the dynamics of rail freight transportation in the Baltic Sea Region countries.

#### Evaluation of the dynamics of rail freight transportation

The results of the calculations of uniformity of rail freight transportation development in the Baltic region countries are presented in Table 3 according to the methodology described above.



**Figure no. 8: Depicting the trajectory of rail freight development  $i$ -time period**  
 (where a – positive development, b – negative development);  
 ( $P_i - i$ - is the size of the time period of transportation at its beginning;  
 $P_{i+1}$  the same value, at the end of time period

**Table no. 3: The significance of the development of rail freight transport in the Baltic States**

Country	Denmark	Estonia	Latvia	Poland	Lithuania	Finland	Sweden	Germany
Uniformity indicator $D^T$	0.985	0.322	0.408	0.887	0.592	0.863	0.903	0.956

The second indicator of the dynamics of rail freight transportation, namely, the intensity of transport, can be determined as follows:

$$D_j^I = \frac{Q_j^T}{Q_j^b}, \quad (3)$$

where:

$D_j^I$  – intensity of rail freight transportation in country  $j$ ,

$Q_j^T$  –  $j$  – the size of the country's transportation at the end of the period under review, and

$Q_j^b$  – the same value at the beginning of the period under consideration.

Table 4 shows the results of the calculation of the intensity indicator for rail freight development.

As can be seen from Table 4, the development of transportation in all countries except Denmark and Lithuania was negative.

**Table no. 4: Indicators of intensity of freight transport development in the Baltic Region Countries in a year 2008-2017**

Country	Denmark	Estonia	Latvia	Poland	Lithuania	Finland	Sweden	Germany
Intensity indicator $D^I$	1.241	0.529	0.870	0.944	1.050	0.882	0.985	0.928

*Source: comprised by authors.*

We will set the indicator of the dynamics of rail freight transportation as a measure of equilibrium  $D^T$  and intensity indicator  $D^I$  product:

$$D^D = D^T \cdot D^I. \quad (4)$$

The results of the calculations are presented in Table 5.

**Table no. 5: The Importance of the rail freight transportation dynamics indicator for the Baltic Countries during 2008-2017**

Country	Denmark	Estonia	Latvia	Poland	Lithuania	Finland	Sweden	Germany
Dynamics indicator $D^D$	1.222	0.170	0.355	0.837	0.622	0.761	0.899	0.887

*Source: compiled by the authors.*

The objective of analyzing the dynamics of rail freight transportation can also be applied to compared countries. In this case, we will determine the traffic intensity indicator for the  $j$  country:

$$\tilde{D}_j^I = \frac{Q_j^f}{Q_b^{\min}}, \quad (5)$$

where:

- $\tilde{D}_j^I$  – comparative indicator of the intensity of  $j$  country transportation;  
 $Q_b^{\min}$  – the value of shipments at the beginning of the period in question for the country where the value was the lowest.

The integrated dynamics will be set as the  $j$ -th equilibrium index for the country  $D_j^T$  and intensity indicator  $\tilde{D}_j^I$  product:

$$D_j^D = D_j^T \cdot \tilde{D}_j^I . \quad (6)$$

The results of the calculations for the countries concerned are presented in Table 6.

**Table no. 6: Comparison of dynamics of freight transportation by rail during 2008-2017 between the Baltic countries (reference point – Danish freight rates for 2008-2017)**

Country	Uniformity indicator of transport		Intensity indicator of transport		Dynamics indicator of transport	
	Value	Place	Value	Place	Value	Place
Denmark	0.985	1	1.0	8	0.985	8
Estonia	0.322	8	15.902	2	5.120	6
Latvia	0.408	7	17.157	1	7.009	2
Poland	0.887	4	4.681	6	4.152	5
Lithuania	0.592	6	13.910	3	8.235	1
Finland	0.863	5	5.311	5	4.583	4
Sweden	0.903	3	5.344	4	4.825	3
Germany	0.956	2	3.242	7	13.099	7

For further development of rail freight transportation, it is important to determine the relationship between the dynamics of transportation and the indicators that reflect the country's development. In most cases, this indicator is taken as the gross domestic product per capita. This relationship has been established on the basis of correlation-regression analysis. The correlation coefficient between the dynamics of rail freight transportation and GDP has been found to be greater than 0.8.

## Conclusions

1. Freight transportation by railways is one of the most important factors contributing not only to the economic development of the country, but also to related processes, such as regional social, ecological development, city urbanization and so on. Further development of rail freight transport requires new research, covering aspects that are not yet widely considered. One of these is the search for opportunities to quantify the actual state of development and trends. This trend is adequately reflected in the dynamics of rail freight transport.
2. The dynamics of freight transportation by rail has been reflected upon two indicators: the uniformity and intensity of transportation. The uniformity of transportation can be defined as the ratio between the size of the length of the period considered and the size of

the actual development trajectory. The intensity of the shipments can be determined as the ratio of the size of the carriage at the end of the period in question to that of the beginning of the period considered.

3. Calculations have shown that all the countries concerned, with the exception of Denmark, are characterized by a negative development of freight transport by RT. This is due to the fact that the high degree of transportation uniformity is outweighed by the decreasing intensity. From this fact it can be concluded that freight transportation by rail is losing competition among the other modes of transportation.

4. Correlation-regression analysis has shown that there is a fairly strong correlation between the countries' Gross Domestic Product per capita, e.g., an indicator of the dynamics of the country's economic development and freight transportation by rail.

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