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RESEARCH ON RELATIONSHIP BETWEEN FREIGHT TRANSPORT AND TRANSPORT INFRASTRUCTURE IN SELECTED EUROPEAN COUNTRIES

Summary. The article deals with research on the relationship between the performance of road and rail freight transport and transport infrastructure in EU countries. The authors of the article examined the relationship between transport performance and transport infrastructure by correlation and regression analyses. Verification of the statistical significance of the regression model was also performed. The main objective of the contribution is to find out what are the relationships and influences between transport infrastructure and development of transport performance. Research has shown that the strength of the relationship between transport infrastructure and transport performance is different for states. There are strong dependencies as well as strong independent relationships between the transport infrastructure and transport performance.

1. INTRODUCTION

Transport is an indispensable basis for the support of almost all sectors of the economy. It is necessary to support and safeguard social and economic processes connected to transport [1]. Transport services are important for economic growth and society development [2]. It has a wider effect on microeconomic factors of productivity such as the labor market, domestic and international trade, investment and innovation. Transport infrastructure is an integral part of a transport system of any city or state. In connection to the development of societies and intensification of international relations owing to the globalization processes, the importance of transport as a factor for economic and social development has enhanced [3]. Infrastructure development is one of the visible signs of technological progress. Many studies state that transport infrastructure is one of the most important factors for the regions' development, which enables the creation of new businesses or supports contacts with other regions. Many different factors affect the economic growth, but they are all directly or indirectly related to infrastructure development [4, 5]. As an example, it may be given that the construction of motorways increases regional accessibility and enhances human activities along the transportation routes. Well-developed transport infrastructure can be seen as a precondition for regional economic integration. For instance, transport of agricultural products can develop faster and faster in farming areas. Transport accessibility is determined by the way the area is developed, making it possible to move in various conditions [6]. What is the correlation between the development of the transport infrastructure and the growth of the freight transport performance in road and rail transport? Growth in transport performance is related to the growth of gross domestic product [19]. Does the pace of changes in transport infrastructure increase transport performance in selected European

countries? These two-research questions were taken into consideration by authors and are discussed in this contribution.

2. THE IMPORTANCE OF TRANSPORT INFRASTRUCTURE

One of the most important presumption and factors of the social and economic development of the states and their regions is road infrastructure. This is also true in the Slovak Republic, as road transport is the most widespread transport sector [7].

The development of transport infrastructure has been regarded long as the main instrument for promotion of economic development. Several studies point to a close link between investment in infrastructure and the economic development of a region [8, 9, 10]. Among the different types of infrastructure, transport infrastructure is considered to be one of the most important by the policy makers, as transportation costs are very crucial in decision on companies' locations as well as economic development of a region. However, it has been a matter of debate whether development of transport infrastructure promotes economic development or economic development promotes development of transport infrastructure or there is each other feedback effect. Each of these points of view has found theoretical support. Endogenous growth theory supports the view that investment in infrastructure promotes economic development [11- 14]. On the contrary, according to Wagner's law, economic development leads to investment in public infrastructure [15, 16]. Tuhin Subhra Maparu and Tarak Nath Mazumder showed existence of long-run relationship between transport infrastructure and economic development and that the direction of causality is from economic development to transport infrastructure in most of the cases, thus drawing support in favor of Wagner's law [17].

It can be stated that from a spatial point of view, the transport network of the Slovak Republic is relatively well developed and sufficiently covers the territory of the Republic. The biggest problem is the currently unfinished sections of motorways and express roads. The reconstruction of the railway routes is also progressing slowly. However, compared with more advanced countries of Europe and in particular in terms of the claims placed on it, its quality is very bad. There are also regional differences in the quality of transport networks, which can have consequences in terms of increasing economic and social disparities between different parts of the country.

Practice shows that the quality of transport infrastructure is an aspect that determines the direction of foreign investment. However, it is not possible to assert with certainty that foreign investments would always be directed to the region in building a sufficient transport infrastructure.

To explore the issue, chosen countries (countries are showed in tab.1) in Europe were selected to obtain all the necessary data on spent power and infrastructure at the same time for both road and rail branches of transport. Therefore, data and research are reported for selected countries only. The authors have been able to analyze this process for 27 countries for road transport and 26 countries for rail transport.

In the graph given in Fig. 1, it is possible to see that the length of infrastructure for these countries together gradually increases. Based on this development, it could also be expected to increase transport performance. The development and length of road infrastructure is differentiated for individual European countries. It can be argued that almost all the countries have seen the growth of infrastructure. Decrease of infrastructure length occurred in Czech Republic, Germany*, Spain, Croatia, Latvia, and Netherland.

Based on this development, increment of transport performance could also be expected. The development and length of road infrastructure is different for individual European countries. It can be argued that almost all countries have seen the growth of infrastructure. Decrease occurred in Czech Republic, Germany*, Croatia, Latvia and Slovenia.

The table 1 shows the length of the road network in Europe. From the European Statistical Office (Eurostat) database, data were selected in the category "Length of other roads by category of roads". Data in the so-called category "Total" include state roads, provincial roads and communal roads.

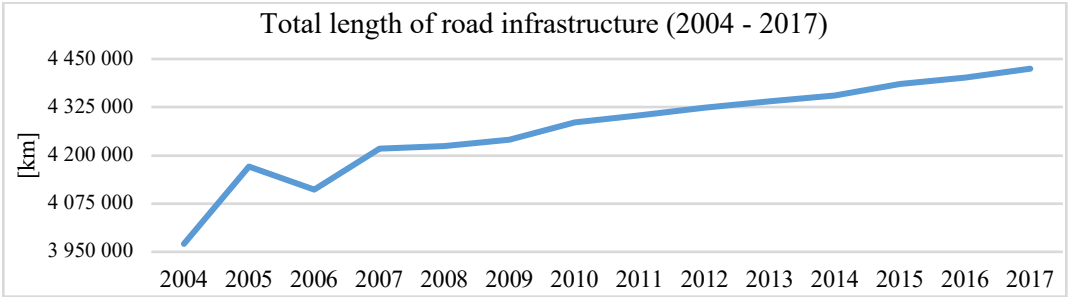

Fig. 1. Development of road infrastructure for selected European countries for the period 2010-2016

Table 1

Length of road infrastructure (Total) in selected European countries (km)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Belgium	47 878	43 847	43 017	42 085	38 356	36 174	35 002	33 107	32 105	32 796	31 808	36 078	35 192	34 220
Bulgaria	11 961	14 371	13 765	14 624	15 322	17 742	19 433	21 214	24 372	27 097	28 926	32 297	34 277	35 150
Czechia	46 011	43 447	50 376	48 141	50 877	44 955	51 832	54 830	51 228	54 893	54 092	58 715	50 315	44 274
Denmark	23 114	23 299	21 254	20 960	19 480	16 876	15 018	16 120	16 679	16 015	16 184	15 500	16 094	15 502
Germany*	303 752	310 103	330 016	343 447	341 532	307 547	313 104	323 833	307 009	305 744	310 142	314 816	315 774	313 149
Estonia	5 099	5 824	5 548	6 417	7 354	5 340	5 614	5 912	5 791	5 986	6 310	6 363	6 716	6 767
Ireland	17 144	17 910	17 454	19 020	17 402	11 687	10 939	10 108	9 976	9 215	9 751	9 900	11 616	11 530
Spain	220 822	233 230	241 788	258 875	242 983	211 895	210 068	206 843	199 209	192 597	195 767	209 390	216 997	218 323
France	212 201	205 284	211 445	219 212	206 304	173 621	182 193	185 685	172 445	171 472	165 225	162 440	159 655	167 691
Croatia	11 587	11 322	11 962	11 552	11 042	9 426	8 780	8 926	8 649	9 133	9 381	10 439	11 337	11 834
Italy	196 980	211 804	187 065	179 411	180 461	167 627	175 775	142 843	124 015	128 724	117 813	116 820	112 637	119 687
Lithuania	12 279	15 908	18 134	20 278	20 419	17 757	19 398	21 512	23 449	26 338	28 067	26 485	30 974	39 099
Luxembourg	9 575	8 803	8 807	9 562	8 965	8 400	8 694	8 835	7 950	8 606	9 599	8 850	9 324	9 414
Hungary	20 608	25 152	30 479	35 805	35 759	35 373	33 721	34 529	33 736	35 818	37 517	38 353	40 002	39 684
Netherlands	89 695	84 163	83 193	77 921	78 159	72 675	76 836	75 543	70 085	72 081	72 338	68 900	67 779	67 533
Austria	39 186	37 044	39 187	37 402	34 313	29 075	28 659	28 542	26 089	24 213	25 260	25 458	26 138	25 978
Poland	102 807	111 826	128 315	150 879	164 930	180 742	202 308	207 651	222 332	247 594	250 931	260 713	290 749	335 220
Portugal	40 819	42 607	44 835	46 203	39 091	35 808	35 368	36 453	32 935	33 741	34 863	34 871	34 877	34 186
Romania	56 612	58 788	57 288	59 524	56 386	34 269	25 889	26 349	29 662	34 026	35 136	39 023	48 176	54 704
Slovenia	9 007	11 032	12 112	13 734	16 261	14 762	15 931	16 439	15 888	15 905	16 273	17 909	18 707	20 814
Slovakia	18 527	22 566	22 212	27 159	29 276	27 705	27 575	29 179	29 693	30 147	31 358	33 540	36 139	35 411
Finland	32 290	31 857	29 715	29 819	31 036	27 805	29 532	26 863	25 460	24 429	23 401	24 488	26 846	27 966
Sweden	36 949	38 575	39 918	40 540	42 370	35 047	36 268	36 932	33 481	38 147	41 964	42 058	42 673	42 988
U. Kingdom	162 654	161 285	165 479	170 991	160 296	139 536	146 685	148 733	150 949	139 703	135 393	139 245	155 042	156 716
Norway	17 460	18 247	19 387	19 375	20 595	18 447	19 751	19 188	20 171	21 025	21 594	21 147	20 910	20 065
Switzerland	15 575	15 302	14 896	14 212	13 911	13 174	13 237	13 567	12 966	12 817	12 774	12 441	12 036	11 947
Overall	1 760 592	1 803 596	1 847 647	1 917 148	1 882 880	1 693 465	1 747 610	1 739 736	1 686 324	1 718 262	1 721 867	1 766 239	1 830 982	1 899 852

** Germany (Total includes data only for state roads and provincial roads).*

Fig. 2 shows the development of railway infrastructure for the countries together. Growth in the years 2004 to 2016 was fluctuating. Compared with 2004 and 2017, there is a decline in infrastructure length in almost all the countries. The increase between 2004 and 2017 is confirmed in case of nine countries (Ireland, Spain, Latvia, Lithuania, Luxembourg, Hungary, Netherlands, Norway, Switzerland and Slovakia).

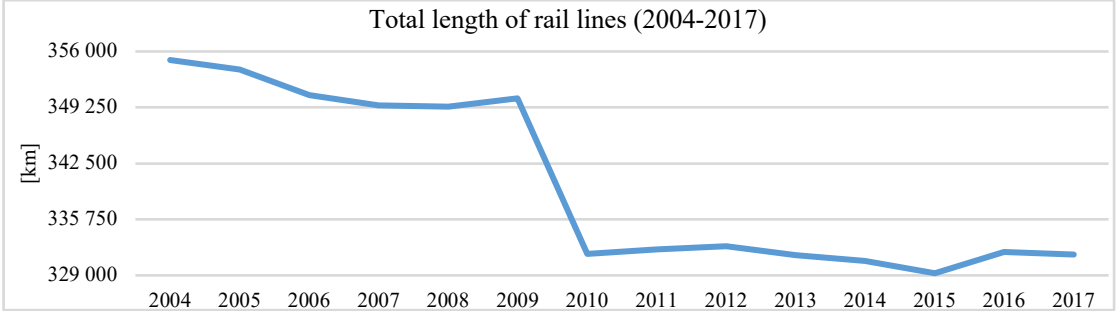

Fig. 2. Development of railway infrastructure length in selected countries in 2010-2016.

In Table 2, the authors present the data connected to the entire length of railway infrastructure for individual countries of Europe. The data were obtained from the Eurostat database in the "Length of tracks- Total" category. Data in the "Total" category include electrified and non-electrified rail tracks.

Table 2

Length of railway infrastructure in European countries (km)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Bulgaria	6 238	6 025	5 990	5 967	5 923	5 888	5 831	5 661	5 658	5 540	5 493	5 486	5 486	5 468
Czechia	15 925	16 156	15 844	15 810	15 716	15 677	15 666	15 656	15 636	15 607	15 578	15 570	15 539	15 519
Denmark	2 804	2 663	2 663	2 663	2 627	2 627	2 627	2 627	2 636	2 636	2 636	2 633	2 573	2 560
Germany	70 557	70 557	70 557	70 557	70 557	70 557	69 278	69 222	69 395	69 247	69 092	67 400	67 400	67 400
Estonia	1 587	1 798	2 733	2 200	2 141	2 166	2 167	2 164	2 164	2 146	2 146	2 144	2 141	2 141
Ireland	1 912	1 912	1 886	1 834	1 889	2 371	2 384	2 384	2 421	2 421	2 421	2 421	2 421	2 421
Spain	17 881	17 315	17 485	16 287	15 721	15 881	18 967	19 166	19 285	20 861	20 761	21 122	22 080	21 853
France	49 063	49 111	49 111	49 644	50 325	51 217	30 709	31 254	31 800	30 318	29 335	28 987	28 364	28 120
Croatia	4 104	4 104	4 098	4 096	4 104	4 103	4 102	4 101	4 105	4 090	4 014	3 968	3 950	3 942
Italy	22 277	22 999	23 193	23 385	23 835	24 179	24 216	24 240	24 277	24 292	24 278	24 286	24 435	24 585
Latvia	2 583	2 583	2 583	2 583	2 565	2 206	2 202	2 202	2 161	2 161	2 214	2 217	2 217	2 217
Lithuania	2 200	2 187	2 187	2 180	2 180	2 182	2 184	2 184	2 189	2 189	2 189	2 336	2 336	2 336
Luxembourg	275	275	275	619	619	614	614	614	621	621	621	621	621	621
Hungary	12 735	12 735	9 513	9 223	9 208	9 208	9 178	9 446	9 421	9 523	9 359	9 358	11 424	11 588
Netherlands	2 811	2 913	2 776	2 895	2 896	2 886	3 016	3 013	3 013	3 032	3 031	3 058	3 223	3 284
Austria	5 766	5 782	5 818	5 793	5 784	5 356	5 351	4 917	4 985	4 950	4 956	4 937	4 917	4 953
Poland	38 781	38 920	38 803	38 852	38 081	38 132	37 840	38 053	37 642	36 939	37 455	37 572	37 386	37 195
Portugal	3 562	3 553	3 553	3 525	3 528	3 528	3 532	3 483	3 239	3 242	3 244	3 244	3 244	3 244
Romania	21 360	21 228	20 677	20 668	20 648	20 520	20 482	20 129	20 077	20 284	20 241	20 155	20 157	20 144
Slovenia	2 193	2 193	2 193	2 192	2 193	2 187	2 187	2 177	2 177	2 178	2 178	2 178	2 178	2 178
Slovakia	3 660	3 658	3 658	3 629	3 623	3 623	3 622	3 624	3 631	3 631	3 627	3 626	3 626	3 626
Finland	8 596	8 587	8 830	8 816	8 848	8 847	8 862	8 885	8 883	8 523	8 485	8 483	8 520	8 513
Sweden	15 381	15 360	15 318	15 297	15 351	15 487	15 497	15 601	15 633	15 468	15 370	15 424	15 459	15 568
U. Kingdom	33 000	31 482	31 105	31 093	31 082	31 119	31 324	31 544	31 764	31 781	31 809	31 883	31 910	31 735
Norway	4 334	4 334	4 338	4 374	4 341	4 151	4 199	4 191	4 136	4 143	4 152	4 152	4 164	4 208
Switzerland	3 381	3 399	3 563	3 349	3 557	3 599	3 574	3 551	3 558	3 592	4 019	3 976	4 034	4 036
Overall	352 966	351 829	348 750	347 531	347 341	348 311	329 610	330 089	330 506	329 415	328 703	327 237	329 805	329 455

3. THE DEVELOPMENT OF TRANSPORT PATHWAYS AND ROAD TRANSPORTATION IN EU COUNTRIES

3.1. Road freight transport

Fig. 3 illustrates the development of road freight transport performance in selected European countries.

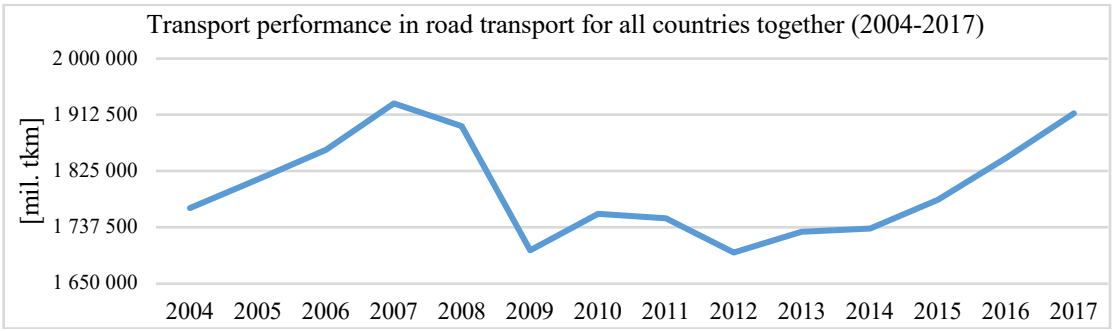

Fig. 3. Development of transport performance of road freight transport in European countries

When comparing transport performance and infrastructure in road freight transport (Fig. 3), it is clear that between 2004 and 2012, there is a difference in development. Since 2012, transport performance has begun to increase. From this year onward, the transport performance and infrastructure length of the countries have been steadily rising. This estimation would suggest that there is a strong correlation between transport performance and the length of the infrastructure. However, it is important to examine these relationships for each country. This relationship is addressed by authors in section 3 of the paper.

Tables 3 and 4 show the statistical data on transport performance in case of freight road transport. Data are expressed individually for selected European countries. Outputs are expressed in millions of tonne-kilometers. The tonne-kilometer ratio is a more reliable indicator because the performance measured only in the tonnes of transferred tonnage would not take into consideration the number of kilometers driven by the transport infrastructure with use of loaded vehicle. The expression in tonne-kilometers (transport performance) expresses the multiple of the weights of things and the distance traveled with these things. For this reason, the transport performance expressed in tkm would be discussed only.

Table 3

Development of road freight transport performance in selected European countries (mil. tkm)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Belgium	47 878	43 847	43 017	42 085	38 356	36 174	35 002	33 107	32 105	32 796	31 808	36 078	35 192	34 220
Bulgaria	11 961	14 371	13 765	14 624	15 322	17 742	19 433	21 214	24 372	27 097	28 926	32 297	34 277	35 150
Czechia	46 011	43 447	50 376	48 141	50 877	44 955	51 832	54 830	51 228	54 893	54 092	58 715	50 315	44 274
Denmark	23 114	23 299	21 254	20 960	19 480	16 876	15 018	16 120	16 679	16 015	16 184	15 500	16 094	15 502
Germany	303 752	310 103	330 016	343 447	341 532	307 547	313 104	323 833	307 009	305 744	310 142	314 816	315 774	313 149
Estonia	5 099	5 824	5 548	6 417	7 354	5 340	5 614	5 912	5 791	5 986	6 310	6 363	6 716	6 767
Ireland	17 144	17 910	17 454	19 020	17 402	11 687	10 939	10 108	9 976	9 215	9 751	9 900	11 616	11 530
Spain	220 822	233 230	241 788	258 875	242 983	211 895	210 068	206 843	199 209	192 597	195 767	209 390	216 997	218 323
France	212 201	205 284	211 445	219 212	206 304	173 621	182 193	185 685	172 445	171 472	165 225	162 440	159 655	167 691
Croatia	11 587	11 322	11 962	11 552	11 042	9 426	8 780	8 926	8 649	9 133	9 381	10 439	11 337	11 834
Italy	196 980	211 804	187 065	179 411	180 461	167 627	175 775	142 843	124 015	128 724	117 813	116 820	112 637	119 687
Latvia	7 381	8 394	10 753	13 204	12 344	8 115	10 590	12 131	12 178	12 816	13 670	14 690	14 227	14 972
Lithuania	12 279	15 908	18 134	20 278	20 419	17 757	19 398	21 512	23 449	26 338	28 067	26 485	30 974	39 099
Luxembourg	9 575	8 803	8 807	9 562	8 965	8 400	8 694	8 835	7 950	8 606	9 599	8 850	9 324	9 414
Hungary	20 608	25 152	30 479	35 805	35 759	35 373	33 721	34 529	33 736	35 818	37 517	38 353	40 002	39 684
Netherlands	89 695	84 163	83 193	77 921	78 159	72 675	76 836	75 543	70 085	72 081	72 338	68 900	67 779	67 533
Austria	39 186	37 044	39 187	37 402	34 313	29 075	28 659	28 542	26 089	24 213	25 260	25 458	26 138	25 978
Poland	102 807	111 826	128 315	150 879	164 930	180 742	202 308	207 651	222 332	247 594	250 931	260 713	290 749	335 220
Portugal	40 819	42 607	44 835	46 203	39 091	35 808	35 368	36 453	32 935	33 741	34 863	34 871	34 877	34 186
Romania	56 612	58 788	57 288	59 524	56 386	34 269	25 889	26 349	29 662	34 026	35 136	39 023	48 176	54 704
Slovenia	9 007	11 032	12 112	13 734	16 261	14 762	15 931	16 439	15 888	15 905	16 273	17 909	18 707	20 814
Slovakia	18 527	22 566	22 212	27 159	29 276	27 705	27 575	29 179	29 693	30 147	31 358	33 540	36 139	35 411
Finland	32 290	31 857	29 715	29 819	31 036	27 805	29 532	26 863	25 460	24 429	23 401	24 488	26 846	27 966
Sweden	36 949	38 575	39 918	40 540	42 370	35 047	36 268	36 932	33 481	38 147	41 964	42 058	42 673	42 988
U. Kingdom	162 654	161 285	165 479	170 991	160 296	139 536	146 685	148 733	150 949	139 703	135 393	139 245	155 042	156 716
Norway	17 460	18 247	19 387	19 375	20 595	18 447	19 751	19 188	20 171	21 025	21 594	21 147	20 910	20 065
Switzerland	15 575	15 302	14 896	14 212	13 911	13 174	13 237	13 567	12 966	12 817	12 774	12 441	12 036	11 947
Overall	1 767 973	1 811 990	1 858 400	1 930 352	1 895 224	1 701 580	1 758 200	1 751 867	1 698 502	1 731 078	1 735 537	1 780 929	1 845 209	1 914 824

The development of transport performance in freight road transport was not uniform. It may be noted that Western European countries have experienced decrease of transport performance (Netherland, France and Italy). On the contrary, East European countries recorded increase of transport performance (Romania, Bulgaria and Hungary). The most noticeable growth was recorded for Poland, where - despite the economic crisis - the transport performance grew.

For the trend of change to be graphically clear, the countries were divided into two groups. The first group consists of countries with a transport performance of less than 100,000 mil. tkm/year (Fig. 4), and the second group with a transport performance of more than 100,000 mil. tkm/year (Fig. 5).

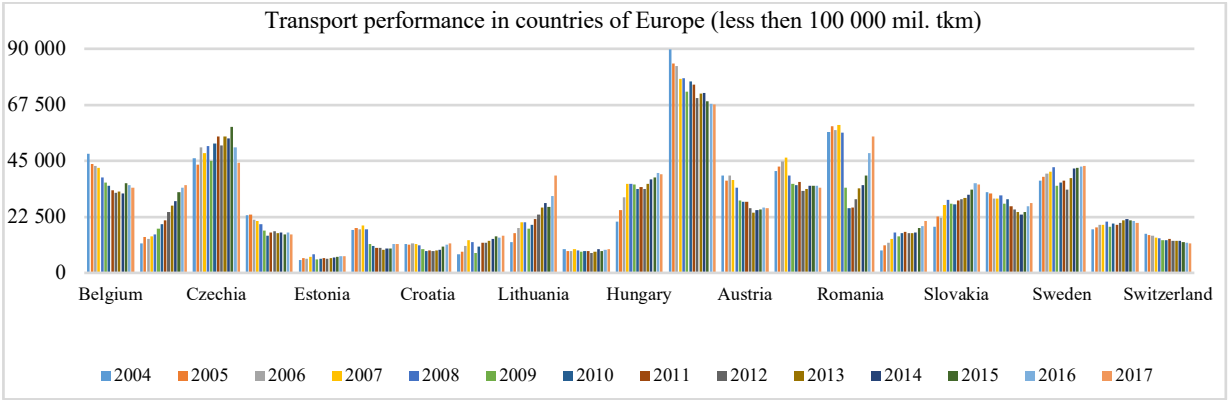

Fig. 4. Developments in road freight transport performance of countries with a transport capacity of less than 100,000 mil. tkm

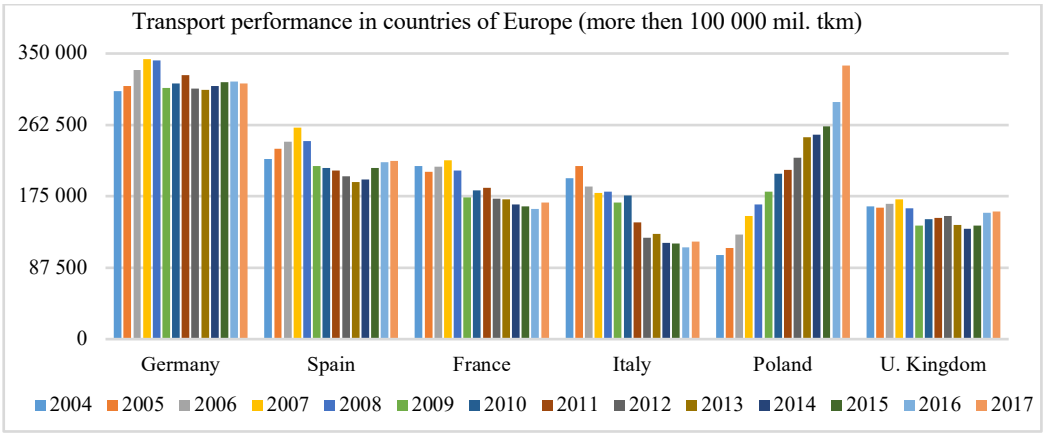

Fig. 5. Developments in road freight transport performance of countries with transport capacity over 100,000 mil. tkm

The performance of rail freight operations for selected states together is shown in Fig. 6. The significant growth is visible between 2010 and 2011. Subsequent decline can be stated a year later. From 2012, slight increase is visible, and it increases until 2015 when a decline occurred.

In the case of rail transport, the development of transport performance and the length of infrastructure is differentiated. A similar behavior is recorded between 2011 and 2012, when significant fall in both indicators occurred. Since 2012, rail transport performance has grown. Infrastructure length shows an alternating fall and growth until 2016.

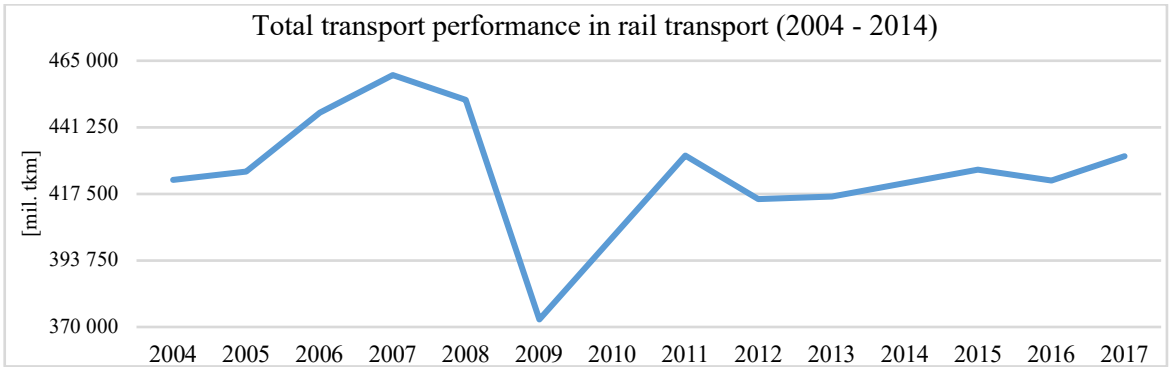

Fig. 6. Development of rail freight transport performance for countries for the period 2010-2016

The table 4 contains data connected to rail freight transport performance.

Table 4

Development of rail freight transport performance in selected European countries (mil. tkm)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Bulgaria	5 692	5 478	5 396	5 241	4 693	3 145	3 064	3 291	2 907	3 246	3 439	3 650	3 434	3 931
Czechia	15 092	14 866	15 779	16 304	15 437	12 791	13 770	14 316	14 267	13 965	14 575	15 261	15 619	15 843
Denmark	2 169	1 976	1 893	1 779	1 867	1 698	2 240	2 614	2 278	2 448	2 453	2 603	2 616	2 653
Germany	86 409	95 420	107 007	114 615	115 652	95 834	107 317	113 317	110 065	112 613	112 629	116 632	116 164	112 232
Estonia	10 488	10 639	10 418	8 430	5 943	5 947	6 638	6 271	5 129	4 722	3 256	3 117	2 340	2 325
Ireland	399	303	205	129	103	79	92	105	91	99	100	96	101	100
Spain	12 436	11 585	11 541	11 237	10 959	7 806	8 913	9 451	9 458	9 338	10 385	11 028	10 550	10 677
France	45 121	40 701	41 179	42 612	40 436	32 129	29 965	34 202	32 539	32 230	32 596	34 252	32 569	33 442
Croatia	2 493	2 835	3 305	3 574	3 312	2 641	2 618	2 438	2 332	2 086	2 119	2 184	2 388	2 592
Italy	22 183	22 761	24 151	25 285	23 831	17 791	18 616	19 787	20 244	19 037	20 157	20 781	22 712	22 335
Latvia	18 618	19 779	16 831	18 313	19 581	18 725	17 179	21 410	21 867	19 532	19 441	18 906	15 873	15 014
Lithuania	11 637	12 457	12 896	14 373	14 748	11 888	13 431	15 088	14 172	13 344	14 307	14 036	13 790	15 414
Luxembourg	559	392	441	574	279	200	323	288	231	218	208	207	201	197
Hungary	8 749	9 090	10 167	10 048	9 874	7 673	8 809	9 118	9 230	9 722	10 158	10 010	10 528	13 356
Netherlands	5 831	5 865	6 289	7 216	6 984	5 578	5 925	6 378	6 142	6 078	6 169	6 545	6 641	6 467
Austria	18 757	18 957	20 980	21 371	21 915	17 767	19 833	20 345	19 499	19 356	20 746	20 814	21 361	22 256
Poland	52 332	49 972	53 622	54 253	52 043	43 445	48 705	53 746	48 903	50 881	50 073	50 603	50 650	54 797
Portugal	2 282	2 422	2 430	2 586	2 549	2 174	2 313	2 322	2 421	2 290	2 434	2 688	2 774	2 751
Romania	17 022	16 582	15 791	15 757	15 236	11 088	12 375	14 719	13 472	12 941	12 264	13 673	13 535	13 782
Slovenia	3 149	3 245	3 373	3 603	3 520	2 817	3 421	3 752	3 470	3 799	4 110	4 175	4 360	5 128
Slovakia	9 702	9 463	9 988	9 647	9 299	6 964	8 105	7 960	7 591	8 494	8 829	8 439	8 370	8 477
Finland	10 105	9 706	11 060	10 434	10 777	8 872	9 750	9 395	9 275	9 470	9 597	8 468	9 456	10 362
Sweden	20 856	21 675	22 271	23 250	22 924	20 389	23 464	22 864	22 043	20 970	21 296	20 699	21 406	21 838
U. Kingdom	22 552	21 427	21 919	21 265	21 077	19 171	18 576	20 974	21 444	22 401	22 143	19 342	17 053	17 167
Norway	2 845	3 182	3 351	3 502	3 621	3 506	3 496	3 574	3 489	3 383	3 539	3 498	3 312	4 040
Switzerland	12 911	12 632	12 152	12 487	12 265	10 565	11 074	11 526	11 061	11 812	12 313	12 431	12 447	11 665
Overall	420 389	423 410	444 435	457 885	448 925	370 683	400 012	429 251	413 620	414 475	419 336	424 138	420 250	428 841

As far as the development of freight transport performance in rail freight transport has grown almost in all countries, German performance was more pronounced. The decrease was recorded in seven countries (Estonia, Latvia, Luxembourg, Finland, Sweden, United Kingdom and Norway). The most pronounced decline was observed in case of Estonia.

4. RESEARCH ON RELATIONSHIP BETWEEN THE PERFORMANCE OF FREIGHT TRANSPORT AND TRANSPORT INFRASTRUCTURE IN THE COUNTRIES OF EUROPE

In the context of research on the relationship between freight transport performance and transport infrastructure in EU countries, methods of regression and correlation were used:

- correlation analysis,
- regression analysis.

The variables in the correlation and regression analyses were chosen as follows:

- dependent (explained) variable *Y* as transport performance,
- independent (explanatory) variable *X* as the length of the infrastructure.

After selection of variables, the correlation coefficient was calculated:

$$r = \frac{cov(x,y)}{s_x * s_y} = \frac{\overline{xy} - \bar{x} * \bar{y}}{\sqrt{\overline{x^2} - \bar{x}^2} * \sqrt{\overline{y^2} - \bar{y}^2}} \quad (1)$$

To determine the correlation strength, the following criteria were identified:

- weak dependence, if $0 < |r| < 0.3$;
- middle dependence, if $0.3 \leq |r| < 0.8$; and
- strong dependence, if $0.8 \leq |r| < 1$.

The dependency we have searched for was modeled by a linear function in the following form (line equation):

$$y = a + bx, \quad (2)$$

where we do not know the coefficients of the line *a* (locating constant) and *b, and* we are looking for the variables *X* and *Y.* The following tables (Tab. 5 and 6) show the results of both analyzes. The significance level was selected at the level $\alpha = 0.01$.

Table 5

Analysis results (road freight transport)

	Country	Correlation coefficient	Determination coefficient	Coefficient *a*	Coefficient *b*	*P-value a*	*P-value X*	*Significance F*
strong direct dependence	Bulgaria	0,9655	0,8911	0	1,166	x	0,000	0,000
	Poland	0,9252	0,9254	0	0,514	x	0,000	0,000
	Slovenia	0,8720	0,9667	0	0,405	x	0,000	0,000
	Lithuania	0,8094	0,9324	0	0,280	x	0,000	0,000
middle direct dependence	Norway	0,7411	0,9971	0	0,212	x	0,000	0,000
	Spain	0,6219	0,9936	0	1,439	x	0,000	0,000
	Slovakia	0,6021	0,9791	0	0,682	x	0,000	0,000
	Czechia	0,5947	0,9931	0	0,388	x	0,000	0,000
	Estonia	0,5550	0,9925	0	0,105	x	0,000	0,000
	Germany	0,3378	0,9985	0	1,374	x	0,000	0,000
	Switzerland	0,3131	0,9935	0	0,192	x	0,000	0,000
weak direct dependence	Sweden	0,1151	0,9738	0	0,194	x	0,000	0,000
	Croatia	0,0777	0,9852	0	0,386	x	0,000	0,000
	Ireland	0,0517	0,9312	0	0,137	x	0,000	0,000
weak indirect dependence	Luxembourg	-0,0373	0,9964	0	3,169	x	0,000	0,000
	Hungary	-0,0719	0,9631	0	0,165	x	0,000	0,000
middle indirect dependence	Netherlands	-0,3355	0,9922	0	0,587	x	0,000	0,000
	U. Kingdom	-0,3699	0,9947	0	0,366	x	0,000	0,000
	Romania	-0,5187	0,9097	0	0,533	x	0,000	0,000
	Italy	-0,6117	0,9257	0	0,633	x	0,000	0,000
	Latvia	-0,7185	0,9595	0	0,201	x	0,000	0,000
	Finland	-0,7608	0,9885	0	0,265	x	0,000	0,000
	Portugal	-0,7615	0,9786	0	3,486	x	0,000	0,000
	Austria	-0,7967	0,9289	0	0,250	x	0,000	0,000
strong indirect dependence	Belgium	-0,8096	0,9789	0	0,242	x	0,000	0,000
	France	-0,9075	0,9811	0	0,177	x	0,000	0,000
	Denmark	-0,9140	0,9723	0	0,248	x	0,000	0,000

Initially, it was created by a linear regression model for each country (25 models). Based on the comparison of *significance level α= 0.1, with P-value a*, linear regression model for each country was created (27 models). Based on the comparison of *significance level α= 0.01,* with *P-value a,* it was determined that the localizing constellation was not significant in 23 cases (road transport) and 21 cases (railway transport). Because of this reason, it was decided to create linear regression models without a constant. The individual model components, the Determination Coefficient, the P-value of the independent variable as well as the P-value model as a whole (*Significance F*) can be found in tab. 5 (Road Transport) and tab. 6 (Rail transport).

Individual countries are ranked according to correlation coefficients, from the strongest direct dependence to the strongest indirect dependence.

Results of the analyses listed in table 5 show that the interconnection of infrastructure with the development of road freight transport performance is varied in the observed countries. Based on our established criteria for determining the strength of the correlation, **strong direct dependence** was found in case of countries such as: Bulgaria, Poland, Slovenia and Lithuania.

Middle direct dependence was observed in case of countries such as Norway, Spain, Slovakia, Czech Republic, Estonia, Germany and Switzerland. Sweden, Croatia and Ireland have a **weak direct dependence**. **Weak indirect dependence** was observed in case of countries such as Luxembourg and

Hungary. **Middle indirect dependence** was reached by countries such as Netherland, United Kingdom, Romania, Italy, Latvia, Finland, Portugal and Austria.

Strong indirect dependence was observed in case of countries such as Belgium, France, and Denmark.

The significance level of the whole model (*Significance F*) and the coefficient *b* (*P - value x*) was less than 0.01 for each model. The determination coefficient for all countries was higher than 0.89. As the determinant coefficients reached such high values, it can be argued that the explained variable is described at more than 89% (depending on the particular country).

Table 6

Analysis results (rail transport)

	Country	Correlation coefficient	Determination coefficient	Coefficient *a*	Coefficient *b*	*P-value a*	*P-value X*	*Significance F*
middle direct dependence	France	0,7695	0,9703	0	0,902	x	0,000	0,000
	Bulgaria	0,7440	0,9566	0	0,706	x	0,000	0,000
	Romania	0,6797	0,9887	0	0,692	x	0,000	0,000
	Slovakia	0,6663	0,9911	0	2,386	x	0,000	0,000
	Croatia	0,3884	0,9736	0	0,650	x	0,000	0,000
	Lithuania	0,3078	0,9941	0	6,168	x	0,000	0,000
weak direct dependence	Finland	0,2433	0,9953	0	1,124	x	0,000	0,000
	Hungary	0,1956	0,9744	0	0,949	x	0,000	0,000
	Netherlands	0,1935	0,9943	0	2,102	x	0,000	0,000
	Poland	0,1312	0,9969	0	1,343	x	0,000	0,000
	U. Kingdom	0,1237	0,9924	0	0,647	x	0,000	0,000
	Czechia	0,1229	0,9962	0	0,945	x	0,000	0,000
	Switzerland	0,0013	0,9926	0	3,255	x	0,000	0,000
weak indirect dependence	Sweden	-0,0209	0,9980	0	1,415	x	0,000	0,000
	Spain	-0,0514	0,9732	0	0,542	x	0,000	0,000
	Latvia	-0,0658	0,9832	0	7,933	x	0,000	0,000
	Austria	-0,1076	0,9900	0	3,802	x	0,000	0,000
	Estonia	-0,1420	0,8015	0	2,816	x	0,000	0,000
middle indirect dependence	Norway	-0,3168	0,9933	0	0,816	x	0,000	0,000
	Denmark	-0,3724	0,9762	0	0,845	x	0,000	0,000
	Portugal	-0,4764	0,9901	0	0,719	x	0,000	0,000
	Italy	-0,4974	0,9864	0	0,894	x	0,000	0,000
	Germany	-0,5569	0,9914	0	1,558	x	0,000	0,000
	Luxembourg	-0,6372	0,6937	0	0,494	x	0,000	0,000
	Slovenia	-0,6405	0,9768	0	1,697	x	0,000	0,000
	Ireland	-0,6509	0,6363	0	0,061	x	0,000	0,000

The following indicators were found for the investigated transport performance and rail infrastructure relationships. **Strong direct and indirect dependence** was not found, whereas **middle direct dependence** was stated in case of countries such as France, Bulgaria, Romania, Slovakia, Croatia and Lithuania. Moreover, it was also concluded that **weak direct dependence** occurred in case of countries such as Finland, Hungary, Netherlands, Poland, United Kingdom, Czech Republic and Switzerland. **Weak indirect dependence** was found for countries such as Sweden, Spain, Latvia, Austria and Estonia. **Middle indirect dependence** is for countries Norway, Denmark, Portugal, Italy, Germany, Luxembourg, Slovenia and Ireland. The significance level of the whole model (*Significance F*) and the *coefficient b* (*P - value x*) was less than 0.01 for all models. The determinant coefficient values were more than 0.9 for 23 of the researched countries. Values lower than 0.9 occurred only in case of Estonia (0.8015), Luxembourg (0.6937) and Ireland (0.6363). It can be argued that the explained variables are described at more than 90% (depending on the country). The year-to-year correlation between transmission capacity and infrastructure length for selected countries was calculated as the next step. This analysis is presented for both road and rail freight transport.

In the graph given in Fig. 7, it can be seen that the strength of the relationship for road non-transport for all the surveyed countries was gradually decreasing. In 2004, the correlation coefficient between transport performance and the length of the infrastructure reached a middle level of direct dependence (0.6043). In 2017, the correlation coefficient reached also a middle direct dependence

(0.545). Based on such data, it can be deduced that the dependence between the freight transport performance and the road freight infrastructure is weaker every consecutive year.

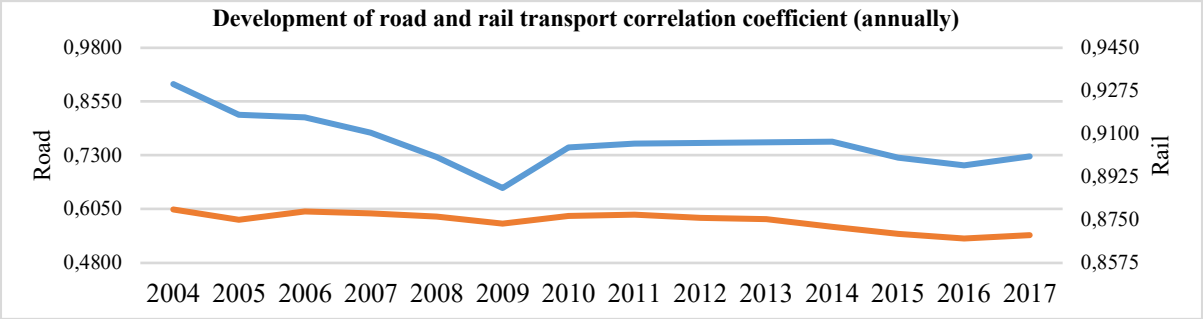

Fig. 7. Development of the correlation coefficient for road transport and railways

In case of rail transport, the development of the correlation force versus road haulage is different. The correlation coefficient has a strong direct dependence between 2004 and 2017. Increment of the correlation coefficient was recorded in 2006, 2010 and 2011. Since 2011, it has been gradually decreasing. In 2017, the correlation coefficient was 0.9008 (strong direct dependence).

From this point of view, it can be deduced that the strength of the relationship between the length of the infrastructure and the transport performance gradually decreased. Table 7 shows the length of road infrastructure (Motorways) in selected European countries.

Table 7

Length of road infrastructure (Motorways) in selected European countries (km)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Belgium	1 747	1 747	1 763	1 763	1 763	1 763	1 763	1 763	1 763	1 763	1 763	1 763	1 763	1 763
Bulgaria	331	331	394	418	418	418	437	458	541	605	610	734	734	734
Czechia	546	564	633	657	691	729	734	745	751	776	776	776	1 223	1 240
Denmark	1 071	1 071	1 071	1 111	1 128	1 128	1 130	1 130	1 143	1 216	1 232	1 237	1 255	1 308
Germany	12 174	12 363	12 531	12 594	12 645	12 813	12 819	12 845	12 879	12 917	12 949	12 993	12 996	13 009
Estonia	96	99	99	96	104	100	115	115	124	140	141	147	145	154
Ireland	192	247	252	269	423	663	900	900	900	897	897	916	916	916
Spain	10 747	11 432	12 073	13 013	13 518	14 021	14 262	14 531	14 701	14 981	15 049	15 336	15 444	15 523
France	10 486	10 800	10 848	10 958	11 042	11 163	11 392	11 413	11 413	11 552	11 560	11 599	11 612	11 618
Croatia	925	1 016	1 081	1 156	1 199	1 244	1 244	1 254	1 254	1 289	1 290	1 310	1 310	1 310
Italy	6 532	6 542	6 554	6 588	6 629	6 661	6 668	6 668	6 726	6 751	6 844	6 943	6 943	6 943
Lithuania	417	417	309	309	309	309	309	309	309	309	309	309	314	324
Luxembourg	146	147	147	147	147	152	152	152	152	152	152	161	161	165
Hungary	569	636	785	858	1 274	1 273	1 477	1 516	1 515	1 767	1 782	1 884	1 924	1 937
Netherlands	2 585	2 600	2 604	2 582	2 637	2 631	2 646	2 651	2 658	2 666	2 678	2 730	2 756	2 758
Austria	1 677	1 677	1 678	1 696	1 696	1 696	1 719	1 719	1 719	1 719	1 719	1 719	1 719	1 743
Poland	552	552	663	663	765	849	857	1 070	1 365	1 482	1 556	1 559	1 640	1 640
Portugal	2 524	2 538	2 545	2 613	2 673	2 705	2 737	2 737	2 988	3 035	3 065	3 065	3 065	3 065
Romania	228	228	228	281	281	321	332	350	550	644	683	747	747	763
Slovenia	483	569	579	578	696	747	768	768	769	771	771	775	775	783
Slovakia	316	328	328	365	384	391	416	419	419	420	420	463	463	482
Finland	653	693	700	700	739	765	779	790	780	810	881	881	890	893
Sweden	1 684	1 677	1 744	1 836	1 857	1 923	1 971	1 957	2 004	2 044	2 088	2 119	2 118	2 132
U. Kingdom	3 638	3 633	3 670	3 674	3 673	3 674	3 672	3 686	3 733	3 756	3 760	3 768	3 764	3 803
Norway	193	264	271	239	253	344	381	393	392	399	425	489	502	523
Switzerland	1 341	1 358	1 361	1 383	1 383	1 406	1 406	1 415	1 419	1 419	1 429	1 440	1 447	1 458
Overall	61 853	63 528	64 910	66 546	68 327	69 889	71 086	71 753	72 967	74 280	74 828	75 863	76 626	76 987

Owing to the fact that a large part of the transport performance is realized in road freight transport on motorways, the correlation coefficients between the transport capacity and the length of the roads in road transport were calculated year to year (2004 – 2017, Fig. 8).

In Fig. 8, it can be observed that the strength of the relationship for all surveyed countries for road freight was gradually decreasing. In 2004, the correlation coefficient between transport performance and the length of highways was analyzed as strong direct dependence (0.938). However, in 2017, the correlation coefficient reached only moderate direct dependence (0.7005).

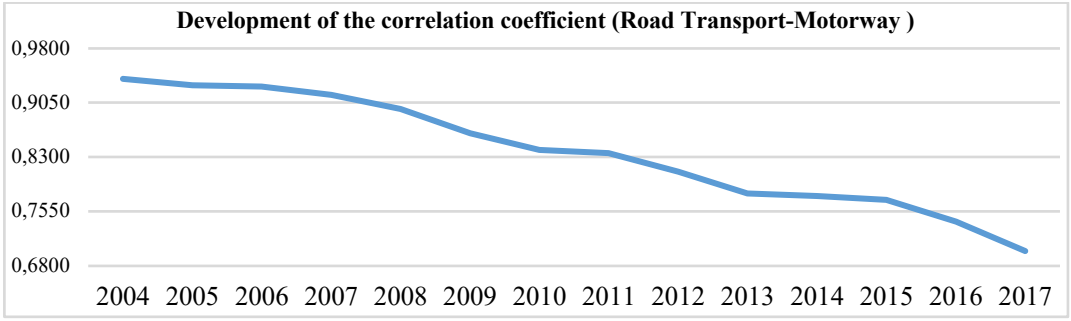

Fig. 8. Development of correlation coefficient for road transport (motorway)

When comparing the results of the correlation coefficients where the "Total" and "Motorway" data were used, it can be seen that the strength of the relationship is differentiated, as well as their course. The strength of the correlation between the transport performance and the length of the motorways was higher. On the contrary, the decrease is more pronounced than "Total" in this case. It can be deduced that the relationship between transport performance and motorways was stronger than with other types of roads (Total).

5. CONCLUSION

The contribution showed that the growth of road infrastructure (motorways mostly) lengths also contributed to transport performance, but the correlation decreased with moderate direct dependence only (0.7005). This means that transport performance increased despite the fact that the length of motorways did not increase. It should be noted that especially in Western European countries, the length of motorways did not increase significantly but affected their permeability by increasing the number of lanes, introducing intelligent transport systems, etc. In the Central and Eastern European countries, large volumes of transport operations are still carried out mainly on 1st class road. Moreover, the increase in transport performance in road freight transport was strongly linked to the growth of gross domestic product (GDP) [19].

The pace of construction in some countries unfortunately does not copy GDP growth and revenue into the state budget. The shift of construction dates and the completion of contiguous sections of motorways may have an influence, particular in international road freight transport, on the direction of transit traffic if other corridors exist.

In rail transport, the correlation between 2004 and 2017 is roughly the same. The difference between 2004 and 2017 is very small - there is a small decrease. It should be noted that this is the total length of railway infrastructure, and the performance in rail transport does not change significantly among the countries under consideration.

It would be interesting to examine the dependence between the length of the motorways and the transport performance per country, especially in road freight transport. The statistical indicators in the field of transport performance also are based on a selective statistical survey, where statistical offices address carriers registered in a given country, as the carriers relocate a large part of its operations abroad.

Therefore, it is necessary to examine the use of built-up infrastructure on the basis of actual vehicle movement data. Data from toll systems, which should be made available in all countries without restriction for research purposes, are very appropriate.

During the construction of the transport infrastructure, it is essential to build the necessary parking and other equipment for road freight transport. This would increase its use as well as road transport safety. Owing to the lack of road freight drivers in EU countries, there is the possibility of increasing the rate of growth of unmanaged combined transport and thereby increasing rail freight performance. This could in turn increase the use of rail transport infrastructure. It is important to mention that the importance of motorways is higher for transit countries.

In the next research, authors using multi-criteria regression could monitor which type of road network is significant for each country.

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