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EVALUATION OF TRANSPORT INFRASTRUCTURE IN REGIONS OF THE CZECH REPUBLIC

Jana Drahošová[1]

Summary: This paper is focused on evaluation of transport infrastructure in regions of the Czech Republic. The main goal is to perform statistical analysis of selected indicators in years 2004–2009.

The results showed that the transport infrastructure is not equally distributed. Higher density of transport network is typical for smaller regions in the northern part of the Czech Republic while large and/or peripheral regions are lacking behind. During the selected period, no significant changes in analyzed regions were observed.

Key words: region, regional competitiveness, transportation, transport infrastructure

INTRODUCTION

Based on extensive study on the factors of regional competitiveness by Martin (2003) the transport infrastructure plays the key role for economic and social development of territories. Its density and quality determines the output of regional economies as well as quality of life of local inhabitants. Together, these two aspects can be denoted as *regional competitiveness*. In the past, this term used to be connected with the economic performance of the territory only. However, the current interpretation covers much wider range of aspects and hereby its measurement is more complicated.

One of the newest ways how to evaluate regional competitiveness is construction of Regional Competitiveness Index (RCI). It has origins in the Joint Research Centre of the European Commission that published the first RCI results (related EU regions at the NUTS 2 level) in year 2010 (Annoni and Kozoska, 2010). It comprises 11 pillars describing different aspects determining the competitiveness. Their selection was built on Bristow´s (2005) definition saying that territorial competitiveness is not only the ability of region to increase incomes but also to create good living conditions for its inhabitants. Namely RCI aggregates following pillars: *institutions, macroeconomic stability, transport infrastructure, health, basic education, higher education, labor market efficiency, size of the market, technological readiness, business sophistication* and *innovations* (Annoni and Kozovska, 2010, pg. 29). To construct the RCI it is necessary to perform detailed analysis separately for all mentioned pillars and calculate their scores.

Although the RCI is primarily aimed at EU regions at the NUTS 2 level and should serve for evaluation of the Cohesion policy efficiency, our future research work aims to

[1] Ing. Jana Drahošová, Tomáš Bata University in Zlín, Faculty of Management and Economics, Department of Regional Development, Public Sector Administration and Law, Mostní 5139, 76001 Zlín, Tel.: +420 775733012, E-mail: j.drahosova@post.cz

perform more in-depth analysis and construct RCI at regional level NUTS 3, using the same indicators and procedure. It is relatively lengthy procedure but results of this paper, analysing and evaluating Transport infrastructure pillar level NUTS 3 in regions of the Czech Republic in selected years, represent important step towards.

1. MATERIAL AND METHODS

The main goal of this paper is to perform statistical analysis of the transport infrastructure in the regions of the Czech Republic at the NUTS 3 level and asses the *Transport infrastructure pillar* in years 2004-2009. The results will become integral part of RCI constructed in frame of our future research.

The data used in the analytical part were downloaded from the Czech Statistical Office (CSO), the Transport Research Centre and Transport yearbooks.

For this purpose RCI by Annoni and Kozovska (2010) will be used. The procedure starts with selection of *candidate indicators* characterizing transport infrastructure. The candidate indicators can be understood as indicators that could be potentially included in RCI. However, performance of multivariate analysis can lead to their reduction. Note, that in this paper selection of candidate indicators is based on publication by Annoni and Kozovska (2010). Next step is the univariate and multivariate analysis performance. The univariate analysis involves descriptive statistics (mean, minimal and maximal value, coefficient of variation, standard deviation) and skewness testing. In case that data are far from the normal distribution and skewness exceeds the recommended limit <-1,5; 1,5> then the logarithmic or inverse transformation must be applied. As the original indicators have different measurement units they are normalized using Z-score standardization. Indicators that do not show positive relationship to the level of competitiveness must be reversed. Within the multivariate analysis, indicator reduction follows to ensure that single latent dimension characterizing transportation is measured only. The method used is called principal component analysis (PCA) that employs Kaiser´s rule to remove unsuitable indicators (OECD, 2008). Practically it means that we must reduce the less suitable indicators until there is the only one principal component having its eigenvalue greater than 1.

Resulting scores evaluating the transport infrastructure in individual regions are calculated from transformed and normalized indicators that successfully underwent the multivariate analysis. Mutual comparison of the final scores of individual regions will be expressed in absolute as well as relative terms. The relative comparisons will be visualized on maps, while the absolute values of the scores and their development in time will be presented on parallel line graph, see fig. 4.

The performed analysis has, however, certain limits, mainly omission of quality and capacity parameters of individual land transport links and airport infrastructure. However, to evaluate overall regional competitiveness and to ensure proper construction of the RCI (where the transport infrastructure score becomes one of the 11 determinants) it was necessary to abstract from the detailed characteristics. It makes limitations of our research.

2. TRANSPORT NETWORKS AS DETERMINANT OF REGONAL GROWTH AND COMPETITIVENESS

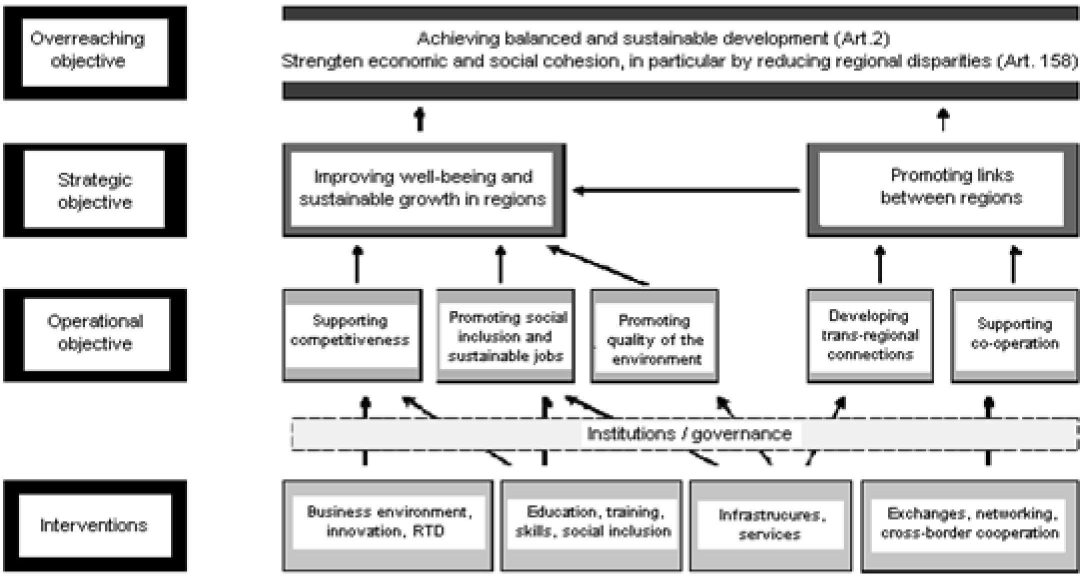
Regions and cities with their infrastructure form the crucial conditions for wealth creation and accumulation. The physical as well as information infrastructure endowment enhances information transmission, goods and services circulation, reduces searching costs, brings new opportunities and improves links among different companies and economic subjects operating in given region (Jacobs, 1969). Generally, the density of the transport network is highly correlated with population density and thus with the degree of urbanization (Cervero, 2001). Specialized infrastructure, transport networks, localized technology and skilled labor are factors that enable quick realization of external economies of scale; lead to first-mover advantage and hereby to higher competitiveness (Martin, 2003).

Regional competitiveness combines competitiveness at the macroeconomic as well as microeconomic level. Therefore also business strategy by Porter (1990) should be mentioned. It specifies four basic drivers of micro-economic competitiveness: production factors, company´s strategy and rivalry, demand conditions and related and supporting industries. In this context, developed transport infrastructure is understood as a kind of production factor and therefore it has substantial impact on competitiveness of individual companies. Analogically the existence of competitive and prosperous companies brings competitiveness to the region where they are located. On one side, these companies contribute to the regional GDP growth; create working positions and source of incomes for inhabitants. On the other hand, competitive companies improve well-being of local people by offering them quality goods and services and by satisfying their needs.

Although infrastructure development has a character of the cost item, due to the multiplication effect based on production function, construction of transport networks is a very important source of revenues. Better infrastructure links boost competitiveness and economic performance; enable efficient production and intensive trade (Transport strategy, 2011). High density and quality of transport infrastructure reduce transportation costs and save time. Modernization of transport (electrified railways) and building ring roads around cities have positive impact on environment and hereby on living conditions of inhabitants.

2.1 Transport infrastructure from European Union´s view

The European Commission defines transport infrastructure as *"the fundamental element for the smooth operation of the internal market, for the mobility of persons and goods and for the economic, social and territorial cohesion of the EU"* (EC, 2011, pg.1). According to the document Transport strategy (2011, pg.2) developed by Ministry of transport of the Czech Republic, the transport infrastructure is defined as the *"tool used to strengthen competitiveness of countries and their regions as well as a tool for interregional disparities reduction"*. Building a new regional transport infrastructure, extension and enhancing existing networks and removing transport bottlenecks therefore contributes directly to fulfillment of the EU Cohesion policy goals. The role of infrastructure within the Cohesion policy and its logical links are presented on the scheme (see Fig. 1).



Source: Ahner (2009)

Fig. 1 – Cohesion policy logical diagram

The most of the existing transport infrastructure has been developed under national policy premises. In order to establish a single, multimodal network that integrates land, sea and air transport networks throughout the EU, the European policy makers decided to establish the Trans–European Networks in Transport (TEN–T), allowing goods and people to circulate quickly and easily between Member Sates and assuring international connections (EC, 2011). The TEN–T has constituted a key element in the re-launched Lisbon strategy for competitiveness and employment in Europe and will play an equally central role in the attainment of the objectives of the Europe 2010 Strategy. As the growth in traffic between EU member states was expected to double between years 2005 and 2020, the investment required to complete and modernize a the TEN–T in the EU–27 amounted to 600 billion EUR (TENT, 2005). However, unlike other sectors, transport infrastructure development depends on public funding, essentially from national budgets. Extensive investments are necessary also from European resources, mainly from the European Investment Bank in form of loans, Cohesion fund, European Regional Development Fund and TEN-T budget.

2.2 Transport networks in the Czech Republic

Strategic location of the Czech Republic in the central Europe brings comparative advantage to the country (Transport strategy, 2011). This advantage can help the Czech Republic to become even more important logistic hub of Europe than it is today and it could attract stable production or innovation centers as well as big foreign company centrals. Most of the Czech motorways and certain important railways are incorporated in the TEN–T. To improve the international freight transport, the European Commission identified two railway and one motorway corridors leading through the Czech Republic to be completed in following years (TENT, 2005):

- **Railway and motorway axis Gdansk–Warsaw–Brno/ Bratislava–Vienna**

Development of this rail and motorway corridor from the Baltic Sea to the Central Europe will provide an unique opportunity to remove traffic from the existing saturated north–south axes from the North Sea.

- **Railway axis: Athens–Sofia–Budapest–Vienna–Prague–Nuremberg/Dresden**

This railway axis will create the main connection from Eastern Europe to the heart of the enlarged EU. Together with the second axis going through Czech Republic it will allow connections between the Baltic Sea, the Aegean Sea and the Black Sea.
According to the Transport strategy (2011) the geographical location of the Czech Republic in the centre of Europe predestines its crucial role in Pan-European transportation network. On the other hand, the current situation in the Czech Republic is - from the quality and functionality point of view – strongly lacking behind the level of the initial 15 Member States of the EU. If the problems with infrastructure are not solved it can bring unfavorable impact such as outflow of investments from the Czech Republic to neighboring regions (Transport strategy, 2011).

3. INFRASTRUCTURE IN THE CZECH REPUBLIC

Based on RCI by Annoni and Kozovska (2010) there are 3 candidate indicators representing transport infrastructure of the regions that enter the application part. The choice was primarily based on literature search, experts´ estimation and data availability. The candidate indicators are: *motorway density, railway density and airport density.*

The descriptive analysis of these 3 indicators characterizing basic transport infrastructure is performed separately for the beginning (2004) as well as ending period (2009). The detailed results are presented in Tab. 1 and Tab. 2.

The main finding resulting from the analysis is that during the years 2004–2009 no significant changes in the area of transport infrastructure occurred. Although the average motorway and road density slightly increased, none of considered regions reached satisfactory level (with respect to the average values typical in western developed countries of the EU). On contrary, slight decline in railway density was noticed. This is result of removal of certain old and non-functional rail sections.

Tab. 1 – Transport infrastructure indicator – descriptive statistics 2004

Transport infrastructure indicator	Motorway and road density	Railway density	Airport density
Unit of measurement	km/km2	km/km2	airports/10 km2
Source of data	Czech statistsical office, calculation	Czech statiststical office, calculation	Transport Research Centre, Transport yearbook, calculation
Mean	0,7007	0,1270	0,1140

Std. Deviation	0,0980	0,0338	0,0483
Coefficient of variation	0,14	0,266	0,424
Skewness	0,034	0,922	1,169
Std. Error of Skewness	0,616	0,616	0,616
Minimum	0,5352	0,0903	0,0600
Region (min value)	ZL	ZL	KV
Maximum	0,8692	0,1910	0,2210
Region (max value)	STČ	ÚST	PAR

Source: Own calculation

Legend: ZL – Zlínský region, KV – Karlovarský region, STČ – Středočeský region, ÚST – Ústecký region, PAR – Pardubický region

Tab. 2 - Transport infrastructure indicator – descriptive statistics 2009

Transport infrastructure indicator	Motorway and road density	Railway density	Airport density
Unit of measurement	km/km2	km/km2	airports/10 km2
Source of data	Czech statistsical office, calculation	Czech statistsical office, calculation	Transport Research Centre, Transport yearbook, calculation
Mean	0,7035	0,1263	0,1144
Std. Deviation	0,0982	0,0345	0,0453
Coefficient of variation	0,140	0,273	0,396
Skewness	0,031	0,887	0,706
Std. Error of Skewness	0,616	0,616	0,616
Minimum	0,5355	0,0903	0,0600
Region (min value)	ZL	ZL	KV
Maximum	0,8731	0,1912	0,1990
Region (max value)	STČ	ÚST	PAR

Source: Own calculation

Legend: ZL – Zlínský region, KV – Karlovarský region, STČ – Středočeský region, ÚST – Ústecký region, PAR – Pardubický region

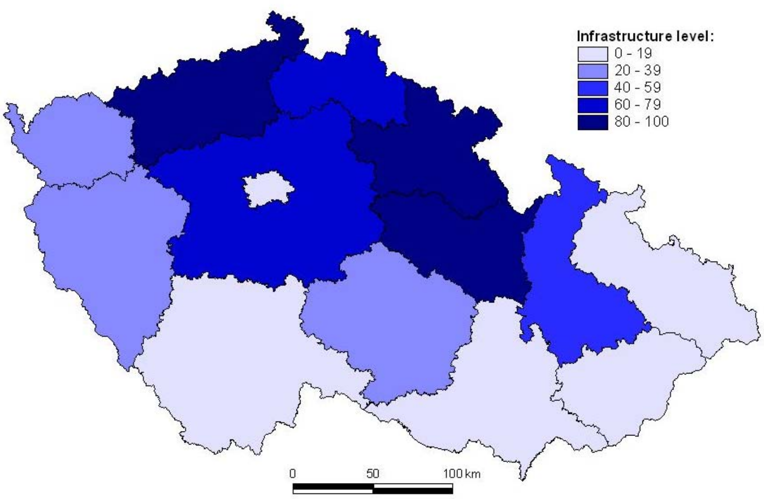
From the quantity point of view Zlínský region evinces the weakest results in the land transport evaluation. Here the weak motorway, road and railway infrastructure density occurs partially due to hilly terrain. This region, neighboring with Slovakia, evinces features of peripheral region and lacks any complete motorway or highway link to the other regions. In case of road and motorway infrastructure, the best situation was in the Středočeský region that surrounds the Capital city of Prague (centre of all business activities and seat of many important companies) and enhances access to this metropolis from all directions. On the other hand, the best position in railway infrastructure is maintained by Ústecký region. The reason is the industrial and mining character of the region where dense railway network (serving primarily for freight transport) was built in the past. When evaluating number of the airports, the crucial role was played by size of the region. Therefore the level of air transport network was measured in units: number of airports per 10 km^2. In this indicator also military airports were included as they undoubtedly belong to the infrastructure. The disadvantage was the omission of factors such as capacity of the airports and existence of regular flight services. However, this would strongly complicate the calculation. With respect to its area the best airport network was in Pardubický and the worst in Karlovy Vary.

The univariate analysis included also skewness testing, supported by histograms presented in the attachments 1 and 2. The results showed that all indicators fit in the recommended skewness limit <-1.5; 1.5> and therefore can be considered as normally distributed. This implies that no data transformation was necessary. As the indicators were expressed in different measurement units it was necessary to convert them into common scale using Z-score standardization. All considered indicators keep positive relationship to the level of competitiveness therefore neither of them had to be reversed.

3.1 Multivariate analysis and innovation score evaluation

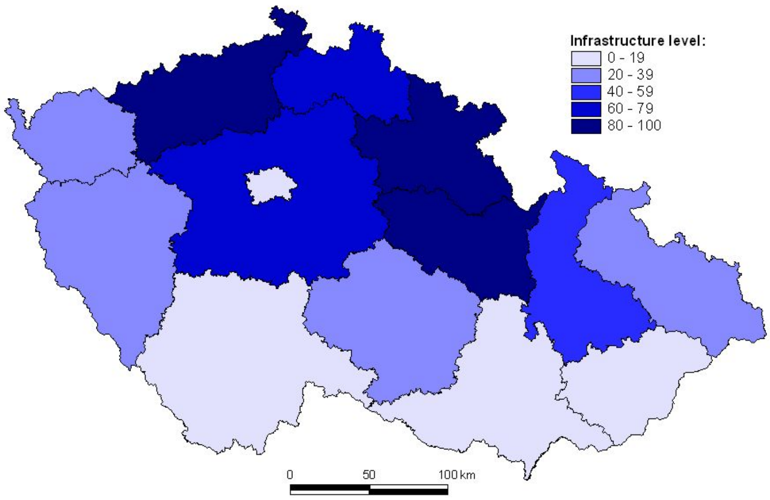
Similarly like in the preceding chapter, the multivariate analysis was performed separately for beginning and ending period. Results of multivariate analysis prove that all candidate indicators (*motorway and road density, railway density* and *airport density*) fit for transport infrastructure evaluation and neither of them had to be removed. However, the indicator railway density was in the edge of acceptability as documented in the attachments 3 and 4 (correlation coefficients of railway density to other indicators were slightly lower than expected, the eigenvalue of second component nearly reached the value of 1 and in the component matrix the railway density had highest correlation coefficient to the second component instead of the first one).

Although the results were not perfect all indicators successfully underwent the multivatiate analysis and therefore could be aggregated into one single *Transport infrastructure score.* The results expressed in relative terms to simplify interregional comparisons are shown in the Figures 2 and 3.



Source: Own calculation

Fig. 2 - Spatial distribution of min-max normalized Transport infrastructure score (2004)



Source: Own calculation

Fig. 3 - Spatial distribution of min-max normalized Transport infrastructure score (2009)

The maps presented above show relative level of transport infrastructure density in regions of the Czech Republic and enable their mutual comparisons. They are constructed on basis of min-max transformed scores presented in the attachment 5. The shade of the color reflects the land and air infrastructure density level - the darker the color the better transport infrastructure in given region.

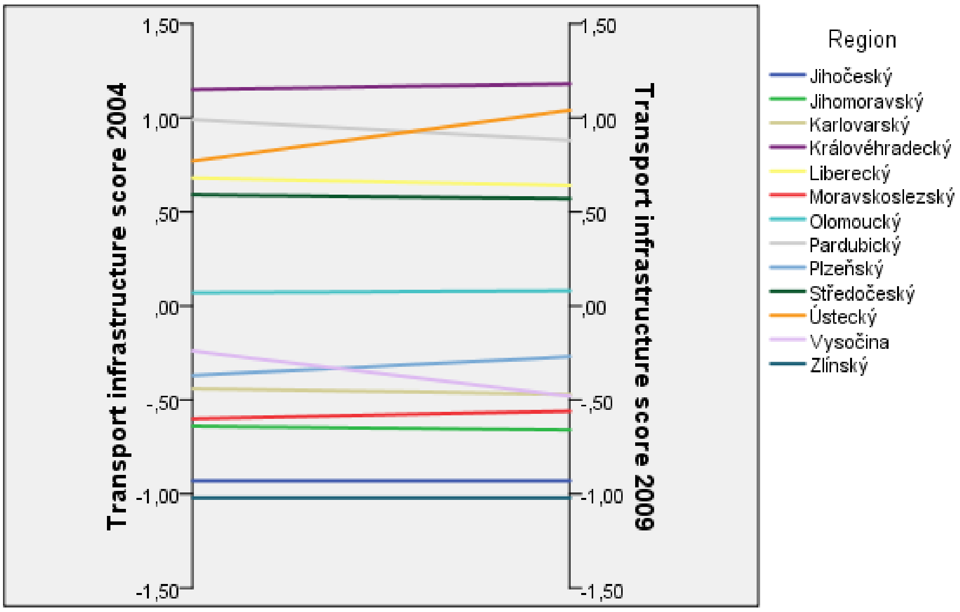
In both periods the strongest position in transport infrastructure was maintained by Královéhradecký, Pardubický and Ústecký region. Královéhradecký and Pardubický regions are fully equipped with road as well as rail infrastructure ensuring proper functioning of their diversified economies and motorway leading to the capital Prague. The high result of Transport infrastructure score of these regions was supported by well developed airport infrastructure. On the other hand, structurally disadvantaged Ústecký region is endowed with dense road and railway network due to its previously developed energetic, metallurgical, chemical, glass industry and brown coal mining. Here the infrastructure was built with the aim of effective functioning of these industries. At the same time the motorway and railway links enable massive trade with Germany (the most important Czech export and import partner).

The second best position is occupied by Liberecký and Středočeský regions. Liberec is small but densely populated region with glass and food industry spread over the whole territory. Therefore it disposes of numerous links connecting individual plants. On contrary, the Středočeský region is large with non-homogenous transport networks concentrated around the capital Prague and in the northern part of the region. The score was negatively influenced by sparse infrastructure of the rural area in the south.

Olomoucký region is placed on the third (middle) position. In the northern periphery of this region the infrastructure density is weak but the southern part hosts 2 important European transport nodes: the motorway and road node in the Olomouc city and railway node located in Přerov.

In the fourth category, there were originally 3 regions: Vysočina, Plzeňský and Karlovarský. These are the typical peripheral regions: Plzeňský and Karlovarský represent rural peripheries and Vysočina belongs to the internal periphery. Such regional character is reflected in the sparse population and hereby weak transport network density. In year 2009 also Moravskoslezský region was integrated to this group. Here the infrastructure is concentrated on the area around Ostrava city and hard coal mines.

The relatively worst performing regions were Jihomoravský, Jihočeský and Zlínský. When excluding the close surroundings of the main regional cities there are extensive rural areas in the Jihomoravský and Jihočeský regions with very weak transport density. Zlínský region is located on the eastern periphery and its hilly terrain complicates the development of transport infrastructure there. All mentioned regions have below-average airport density.



Source: Own calculation

Fig. 4 – Transport infrastructure score development (2004 – 2009)

The parallel line chart confirmed 4 noticeable changes in the Transport infrastructure score during the period 2004–2009. In absolute terms it increased from 0.77 to 1.04 in Ústecký region and from -0.37 to -0.27 in Plzeňský region. This growth is a consequence of the regional airport infrastructure improvement. The strongest decline of infrastructure score was in case of region Vysočina (from -0.25 to -0.48) due to reduction of railways and one airport, and in the Pardubický region (from 0.99 to 0.88) again as a result of airport reduction.

CONCLUSION

The land as well as air infrastructure represents one of the essential factors for well functioning business environment and regional competitiveness. It is noticeable that better results are typical for smaller regions located on the northern and central part of the Czech Republic. Conversely, weak density is typical for rural, peripheral and also for large regions on the south and east. Czech regions, similarly like other territories of the Central and Eastern

Europe (subordinated to socialistic regime in the past) have on average more concentrated rail network than their western neighbors. Conversely, they have substantially less developed motorway and road network crucial for provision of global transport service of the territory. Czech regions are endowed with sufficient number of small airports however, they lack the international meaning. Overall, the strategic geographical location of the Czech Republic constitutes significant development potential for all its regions and thus also for regional competitiveness growth.

The results of the transport infrastructure analysis will be used in the next stage of our research. They will serve for RCI construction and hence will enable evaluation of overall competitiveness of the Czech regions.

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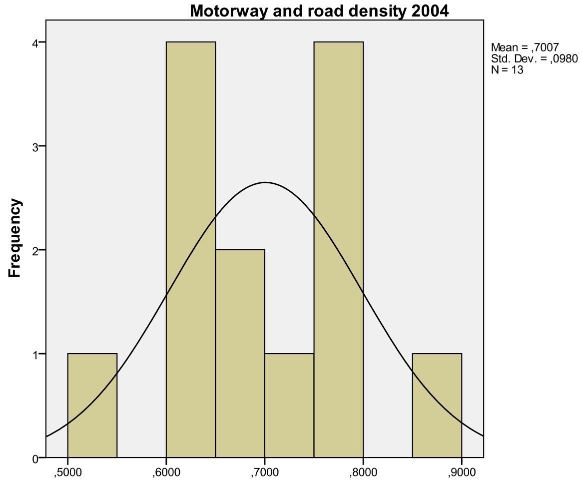
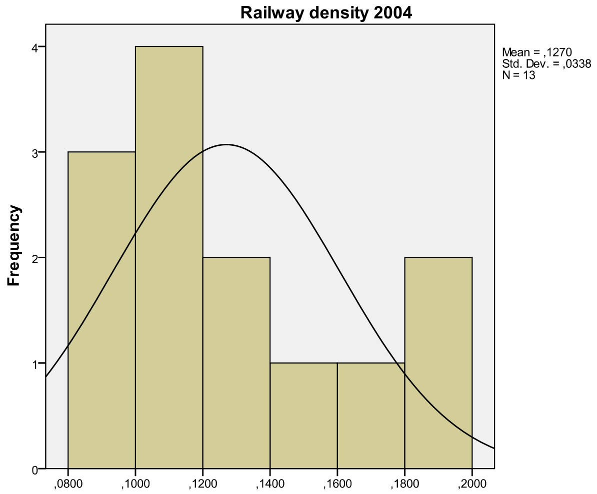
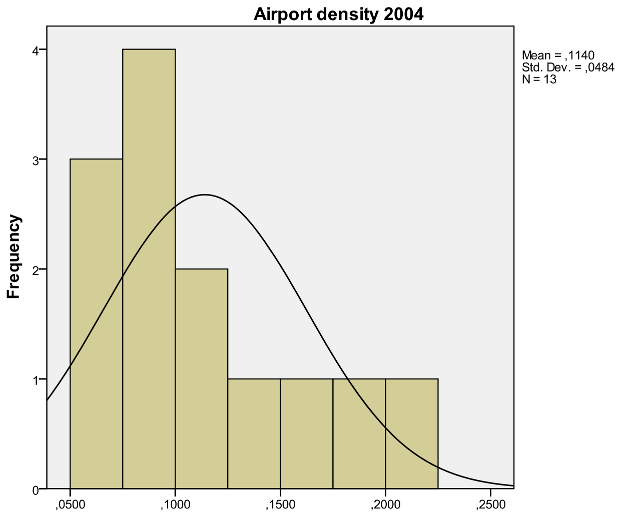
Attachment 1 - Skewness testing 2004

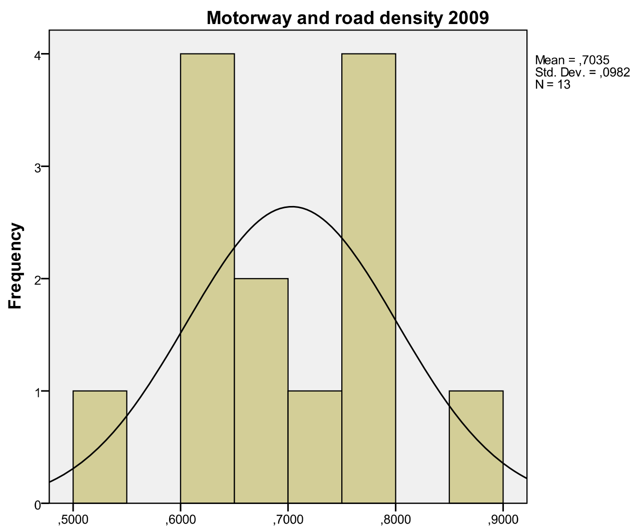


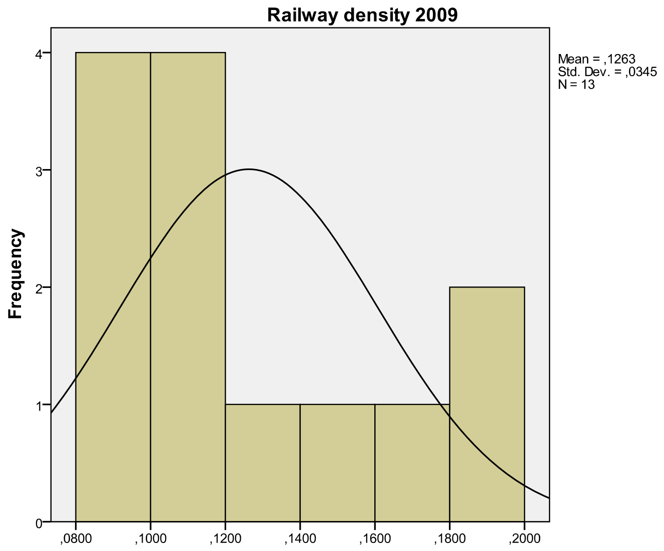


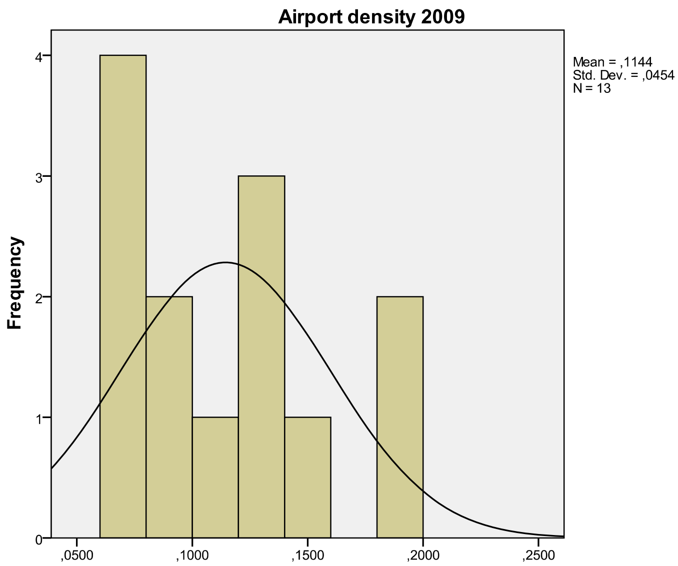


Source: Own calculation

Attachment 2 - Skewness testing 2009







Source: Own calculation

Attachment 3 - Factor analysis 2004

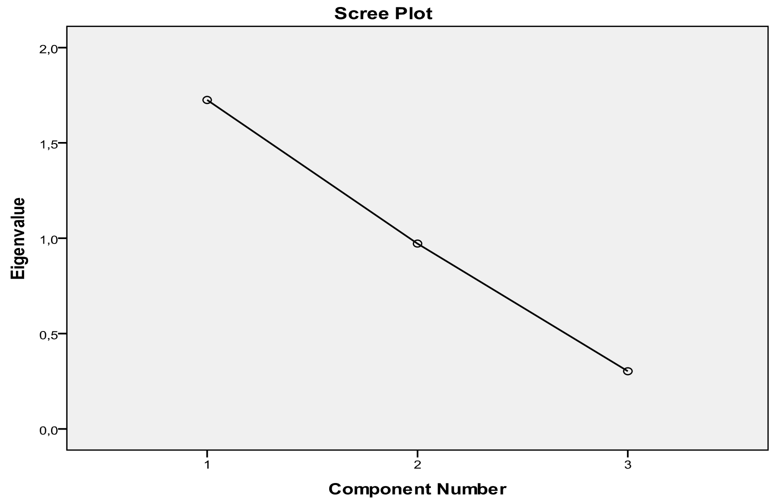
Correlation matrix

		Zscore: Motorway and road density	Zscore: Railway density	Zscore: Airport density
Correlation	Zscore: Motorway and road density	1,000	0,452	0,549
	Zscore: Railway density	0,452	1,000	0,028
	Zscore: Airport density	0,549	0,028	1,000

Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1,725	57,510	57,510	1,725	57,510	57,510
2	0,972	32,401	89,911	0,972	32,401	89,911
3	0,303	10,089	100,000	0,303	10,089	100,000

Scree Plot of eigenvalues



Component matrix

	Component		
	1	2	3
Zscore: Motorway and road density	0,920	-0,008	-0,393
Zscore: Railway density	0,601	0,762	0,242
Zscore: Airport density	0,720	-0,626	0,300

Source: Own calculation

Attachment 4 - Factor analysis 2009

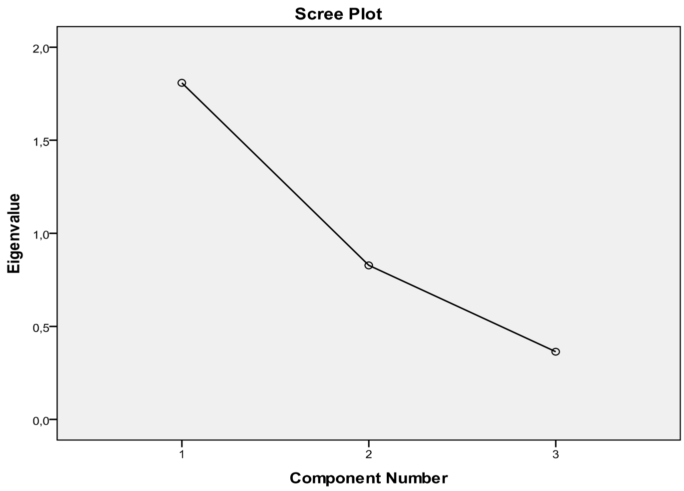
Correlation matrix

		Zscore: Motorway and road density	Zscore: Railway density	Zscore: Airport density
Correlation	Zscore: Motorway and road density	1,000	0,438	0,566
	Zscore: Railway density	0,438	1,000	0,179
	Zscore: Airport density	0,566	0,179	1,000

Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1,808	60,283	60,283	1,808	60,283	60,283
2	0,828	27,593	87,876	0,828	27,593	87,876
3	0,364	12,124	100,000	0,364	12,124	100,000

Scree Plot of eigenvalues



Component matrix

	Component		
	1	2	3
Zscore: Motorway and road density	0,891	-0,065	-0,450
Zscore: Railway density	0,652	0,727	0,214
Zscore: Airport density	0,768	-0,543	0,340

Source: Own calculation

Attachment 5 - Transport infrastructure score evaluation (2004 – 2009)

		Transport infrastructure 2004		Transport infrastructure 2009		Changes (2004 - 2009)	
Region	Region code	Transport infrastr. score 2004	Min-max normalilzed score 2004	Transport infrastr. score 2009	Min-max normalilzed score 2009	Transport infrastr. score	Min-max normalilzed score
Středočeský	STČ	0,59	74	0,57	72	-0,02	-2
Jihočeský	JHČ	-0,93	4	-0,93	4	0	0
Plzeňský	PLZ	-0,37	30	-0,27	34	0,1	4
Karlovarský	KV	-0,44	27	-0,47	25	-0,03	-2
Ústecký	ÚST	0,77	82	1,04	93	0,27	11
Liberecký	LIB	0,68	78	0,64	75	-0,04	-3
Královéhradecký	KH	1,15	100	1,18	100	0,03	0
Pardubický	PAR	0,99	93	0,88	86	-0,11	-7
Vysočina	VYS	-0,24	36	-0,48	24	-0,24	-12
Jihomoravský	JHM	-0,64	18	-0,66	16	-0,02	-2
Olomoucký	OL	0,07	50	0,08	50	0,01	0
Zlínský	ZL	-1,02	0	-1,02	0	0	0
Moravskoslezský	MS	-0,6	19	-0,56	21	0,04	2

Source: Own calculation