COMPARING THE EFFICIENCY OF TRANSPORTATION ROUTES AND CORRIDORS*

-Statistical - mathematical Model

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Abstract

In the broader context of the importance granted to accessibility by the European spatial planning policies, comparing the efficiency of European and national transportation routes and corridors constitutes an issue of particular relevance for Romania. In order to resolve it, this paper proposes a methodology based on potential accessibility, determined by the total population served, and the efficiency of the path, by analogy with the least squares method. Both approaches were applied to internal and European routes.

Keywords: accessibility, transport, least squares method, efficiency, Euro-corridors, optimization.

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The issue of accessibility has a central place on the European agenda of spatial development policies. Their substantiation is based on studies within the framework of the European Spatial Planning Observatory Network (ESPON). One of the first research projects, ESPON 1.1.1, has shown that a balanced and sustainable development corresponds, from a spatial standpoint, to the polycentric model, defined as a „*spatial organization of cities characterized by a functional division of labor, economic and institutional integration, and political cooperation*" (Nordic Centre for Spatial Development, 2003), and based on two types of aspects: the morphology of the territory (number of human settlements, their hierarchy and distribution, including areas of influence) and relationships (fluxes and cooperations) among the elements (settlements) of the territory (Nordic Centre for Spatial Development, 2005). The fluxes are influenced, at their turn by the accessibility. Other ESPON studies have underlined the role of accessibility in developing a polycentric structure (ESPON Monitoring Committee, 2004). Furthermore, accessibility

*** With reference to the European and International routes and transport corridors**

plays a key role in territorial development, since a „*good accessibility of European regions improves not only their competitive position but also the competitiveness of Europe as a whole*" (Spiekermann & Wegener Urban and Regional Research, 2007).

Approaching accessibility seems to have no methodological borders, provided that both in the United States (National Capital Region Transportation Planning Board, 2006), and European Union (Nordic Centre for Spatial Development, 2005) accessibility is defined based on the 45 minutes isochrones. By using the Geographical Information Systems, the methods of studying accessibility can be expanded accounting for the total length or density of road segments with different orientations within the counties or development regions (Petrişor, 2010). Nevertheless, the aforementioned methods present a disadvantage: their use assumes the existence of statistical data. Obtaining such data, particularly recent, could involve elevated costs.

In the national context, this paper proposes two methods that could provide some necessary arguments in shaping the national security corridor, which overlaps with one of the Pan-European Corridor IV route. Thus, this analysis importance is demonstrated by the need to define a network of national interest that can be reasonably long term planned for a progressive modernization and improvement up to 160km/h on sections where it is possible, in terms of cost/benefit. Therefore, the network includes almost all major lines and bear 80% of passenger and freight traffic, while maintaining connections with neighboring countries.

In Europe, the current trend in global development of transportation is generated by countries necessity to create a high-speed railroad infrastructure, which primarily involves reducing travel time upon long distances, and second implies bettering inter-regional accessibility towards remote regions, to stimulate European integration (Willigers *et al*., 2005).

European area includes 27 Member States, of which only 25 have railroads, with exception of Malta and Cyprus. The European development strategy sets forth that creating a Pan-European transport corridor is an important objective. There are different railroads in Europe, both in structure, organization, financing and in growing travel demands.

This article shows and emphasizes a method of optimizing Pan-European Corridors, choosing for their extension toward the areas lacked of these opportunities. Our proposals of set routes encompass the existing railroad routes in the territory of each Member State, with route changes depending on several parameters. Thus, from ten Pan-European Corridors only five of them are found efficient for optimizing, i.e. unconventional corridors II, III, IV, V, and X. Unconventional corridors are those that have not been established by any conference in this field at European level, but were drawn on a plan in accordance with a proven exterior. Thus, the new proposed corridors, the unconventional ones, draw up an opened and connected map, which refers to performance. Thinking on this unconventional map of corridors has the characteristic to recognize other vehicles contribution, and to offer the best option to travel to the desired destination.

The establishment of a system in which all networks are related, is not regarded merely only as a domestic system, but is indicated to be included in an international program. Thus, processing at European level as an efficient system starts right from the concept of "Euro-Corridor". Therefore, economic impulses at local and regional level are very important, within the investments in Euro-Corridor's areas.

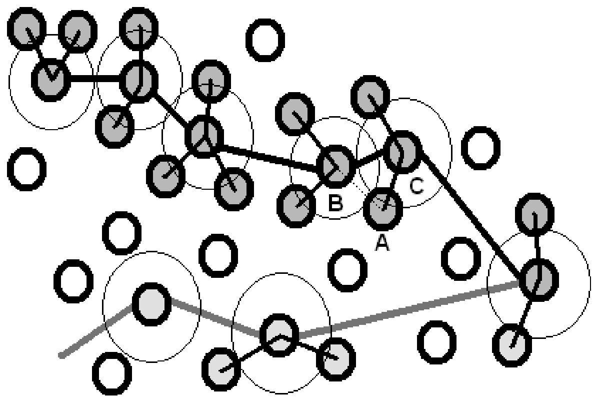
Based on these elements, the current study proposes a statistical-mathematical model for comparing the efficiency of transport corridors based on the construction of indices measuring quantitatively the accessibility based on the importance and proximity of neighboring urban centers, relying on the map of a region and population data.

Measuring potential accessibility based on the importance of neighboring urban centers

The first approach is based on potential accessibility, defined using the 45 minutes isochrones (National Capital Region Transportation Planning Board, 2006; Nordic Centre for Spatial Development, 2005), *i.e.* the settlements accessible by any or specific types of transportation within 45 minutes. Nevertheless, the indicator used in the study was not their actual number, but the total population, in an attempt to measure the importance of the service provided to them. Given that the average speed outside the city limits is 90 km/h, the 45 minutes isochrones correspond to a distance of 67.5 km, rounded up to 70 km in order to account for speeding up, slowing down, and traffic clogs around exits. For each railroad node, their population was added to the one of all other administrative units located within a distance of 70 km. If a certain settlement was located within 70 km from two or more nodes, its population was accounted for the closest node only (*Fig. 1*). 2007 population data were used (National Institute of Statistics, 2008).

Showing the principle of the method based on potential accessibility, used to compare the efficiency of two transportation corridors. City A is closer to city C than to city B; consequently, its population will access the railroad station situated in the city C

Fig. 1

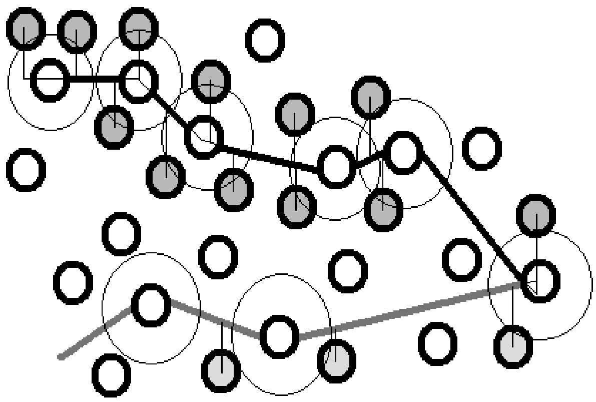


Measuring the efficiency of a route based on the proximity of neighboring urban centers

The second approach is based on the same principle as simple linear regression in statistics (Legendre, 1806), *i.e.*, the least squares method (Dumitrana *et al*., 2006). According to this principle, the optimal path fitting a set of points is the one that minimizes the sum of the squared straight distances between each point and the path (Anghelache, 2006; Odăgescu and Odăgescu, 2009). In this study, the optimal route is the one minimizing the sum of straight distances between the centers of all accessible settlements (defined again based on the 45 minutes isochrones) and each path (*Fig. 2*). The indicator used in this case, sum of squared distances, is a simplified measurement of the efficiency of the route, regardless of eventual deviations determined by the configuration of relief. Computations were made on the North-South direction, corresponding to the least squares method, and, in addition, on the East-West direction, when the orientation of the corridor required the change.

Showing the principle of the method derived from simple linear regression, used to compare the efficiency of two transportation corridors

Fig. 2



The methodologies were applied for the analyses of the Romanian territory only to the settlements with the administrative rank of "city" or "municipality" as defined by the Romanian Law no. 351 of 2001 on the approval of the National Spatial Plan – Section IV, Network of Settlements (Parliament of Romania, 2001).

Also, in terms of national outlook, beginning from Law no. 363 of 2006 requirements on the approval of the National Spatial Plan, Section I Transport Networks, published in The Official Gazette no. 806 of 26th of September 2006, on the forecast hypothesis of the existing a strategic transport corridor for Romania, were compared the characteristics of two routes, namely one for Bucharest – Arad and one for Bucharest – Oradea, using 126 cities for the orthogonal projection method, 51 cities for the projection on E-W direction and 165 cities for the radial projection method.

At the European level, two alternative routes (*Magellan* and *Columbus*) were compared for each corridor. The initial data, based on map measuring, included 274 cities located close to the main railroad stations on the orthogonal direction, and 718 cities for the radial method, compared using the Analysis of Variance (ANOVA).

The national results are presented in Table 1 below. The table contains information on the number of settlements located within 70 km of each railroad station or corridor, and the sum of squared distances, when using the first approach, or total population for the second.

Showing a multi-criteria comparison of the Bucharest – Arad and Bucharest – Oradea corridors

Table 1

Method	**Measure**	**Value for the Bucharest – Arad corridor**	**Value for the Bucharest – Oradea corridor**
Potential accessibility	Total population	2085673	1729108
Potential accessibility	Number of settlements	84	78
Optimal path (N-S)	Sum of squared distances	73457.6	504459.6
Optimal path (N-S)	Number of settlements	56	49
Optimal path (E-W)	Sum of squared distances	13694.29	165641.5
Optimal path (E-W)	Number of settlements	12	1

European results are exemplified both in orthogonal and radial projection methods. It is not necessary that in the two map measuring methods, namely the radial and orthogonal, to have the same cities, but it is perfectly true that on the compared routes, to have the same cities for each projection in part.

Thus, in our case, there is no longer question on the effectiveness of railroad routes, but on the extension of rail service to serve a larger number of cities and population, the argument is even the additional cities and prospective beneficiaries.

In the squared distances case, there were no significant differences, in the scientific literature it is reported the value of statistical test (F=1.6) and the associated p value (p=0.1753>0.05, so insignificant). In distances case, there were found no significant differences, but the results are placed in so-called uncertainty region ($0.05<p \leq 0.1$); it is considered that in this case more data would improve statistical significance. Statistical test value is F=2.12 and associated p value is p=0.0785.

The discrepancies between corridors by orthogonal projection method show a determination coefficient R^2 of 0.097 and a variation coefficient of 70.09. In the context of this analysis (Table 2-3), was achieved a significant statistical result, F-test=6.42, p value<0.001 for overall test, with significant differences according to route - F=19.96, p<0.001, corridor - F=6.41, p<0.001 and their combination - F=2.36, p=0.05.

Analysis of corridors differences by orthogonal method

Table 2

Source	df	SS	MS	F	p
Model	9	789950,59	87772,29	6,42	<0,001
Error	538	7353657,61	13668,51		
Total	547	8143608,20			

Analysis of corridors differences by orthogonal method

Table 3

Variable	DF	SS	MS	F	p
Route (*Magellan* or *Columbus*)	1	272776,07	272776,07	19,96	<0,001
Corridor (II, III, IV, V or X)	4	350684,24	87671,06	6,41	<0,001
Combination corridor - route	4	128911,48	32227,87	2,36	0,05

As it resulted, on the corridors length II, III, IV and V on which was applied this method shows that the route „*Magellan*" is better than „*Columbus*", while on corridor X, things are backwards.

For the radial projection method, the mathematical support by the number of accessible cities (distance limit is 50 km), provides indicators that show a better accessibility of the route through "*Magellan*" and "*Columbus*" methods.

Statistical support is, as with the previous method, Analysis of Variance ANOVA. The method compares the distances averages between different options, in our case for corridors II, III, IV, V and X.

There were occurred significant differences; in scientific literature it is reported value of statistical test (F=16.24) and associated p value (p<0.001, so this is significant). In addition, statistical analysis through bi-factorial analysis of variance, offers a coefficient of determination $R^2 = 0.073$ and CV = 66.75.

Differences analysis between corridors by radial projection method

Table 4

Source	df	SS	MS	F	p
Model	9	1471815,69	163535,08	12,43	<0,001
Error	1430	18811369,43	13154,80		
Total	1439	20283185,12			

Differences analysis between corridors by radial projection method

Table 5

Variable	DF	SS	MS	F	p
Route (*Magellan* or *Columbus*)	1	878636,47	219659,12	16,70	<0,001
Corridor (II, III, IV, V or X)	4	165137,49	165137,49	12,55	<0,001
Combination corridor-route	4	428041,72	107010,43	8,13	<0,001

Thus, in this analysis a statistically significant result was obtained (Table 4-5), F test=12.43, p<0.001 for overall test, and significant differences were found due to route - F=16.70, p<0.001, corridor - F=12.55, p<0.001, and their combination - F=8.13, p<0.001.

The results centralization upon the unconventional route comparison tests

Table 6

Indicators	***Columbus* route indicator value (km)**	***Magellan* route indicator value (km)**	**Optimal value of the indicator[**]**
Total length from cities to route	39.184,03 (orthogonal) 116.004,47(radial)	52.225,29 (orthogonal) 131.424,92 (radial)	*Columbus* (orthogonal) *Columbus* (radial)
Total length between important cities and route, for orthogonal model	C.X-1.511.871,5	C.II-4.858.045,6 C.III-3.227.181,5 C.IV-2.633.247,0 C.V-2.500.074,2	*Magellan*
Number of the most important cities[*] to station-city, for radial model	C.III-21 C.IV-18 C.V-7	C.II-17 C.X-8	*Columbus*

* According to ESPON Programme **option for a maximum or a minimum.

The two orthogonal and radial projections analysis reveal that the two proposed options for each corridor side comparison does not differ significantly, which means that for choosing the best unconventional corridors are needed more criteria. It may be noted that on some parts it is better to choose the "*Magellan*" route and on the other portion is better choosing corridor "*Columbus*" (Table 6).

CONCLUSION

The analysis focused on domestic routes primarily required by national laws, as mentioned above, and then the need to integrate the Romanian railway system in the European Union. Therefore, for combining internal and international routes firstly we decided to begin the analysis around the routes for Pan-European Corridor IV, changing profile according to different parameters.

This Pan-European Corridor IV crosses Romania along two directions, with connections to Central Europe and Turkey, so it provides a positive link with the exterior, and therefore this is the core and the valuable element in this research.

Beginning from designing optimum route on the map, at national level, the two versions chosen for comparison are fairly well defined. Thus, for each projection measurements two common areas were found, namely Constanța to Bucharest of 165.25 km and Giurgiu to Bucharest of 70.9 km. Moreover, even if the route Bucharest - Arad is shorter - 619 km and passes through 6 county municipalities, and variant Bucharest - Oradea offers accessibility for seven municipalities on a length of 649 km, these two criteria are not sufficient for choosing the best rail route security corridor.

Based on the statistical calculations, the results indicate that, regardless of the methodology, the Bucharest – Arad corridor appears to be the optimal route in Romania, provided that it serves most settlements. In addition, each methodological approach underlines some other advantages of the Bucharest – Arad corridor: when looking at the potential accessibility, the corridor appears to serve more people than the Bucharest – Oradea one, and when analyzing the optimal path, the Bucharest – Arad corridor appears to minimize the sum of squared distances from the accessible settlements, disregard of computing them on the North-South or East-West direction.

The comprehensive approaches to European spatial development confirm that the solution cannot be global, but divided in parts. Therefore, also are necessary the results obtained from the map measurement and design of corridor routes, useful in drawing the final version of the Pan-European railroad corridors map.

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