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ACCESSIBILITY STUDY IN REGARD TO BUCHAREST UNDERGROUND NETWORK

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Lucrarea îşi propune să identifice noi sensuri şi valenţe ale accesibilităţii pornind de la legătura dintre aceasta şi caracteristicile demografice ale zonelor servite de reţeaua de metrou. Prin studiul de caz realizat se caracterizează topologic reţeaua de metrou din Bucureşti şi se determină accesibilitatea nodurilor reţelei în vederea stabilirii măsurilor corespunzătoare de dezvoltare. În determinarea accesibilităţii au fost folosite exprimări originale care au condus la formularea de concluzii în ceea ce priveşte dezvoltarea reţelei, dar şi calitatea servirii locuitorilor de către metroul bucureştean.

This paper tries to identify new meanings and aspects of accessibility starting from the correlations within and the demographical characteristics of the zones served by underground network. Through the case study herein, the underground network is topologically characterized and the nodes accessibility is determined for establishing the proper measures of development. The accessibility original approach led to conclusions regarding the network development and the quality of service offered to the inhabitants by the underground network.

Key words: transport network, accessibility, topology

1. Introduction

Connection of spatially separated points is the main purpose achieved by transportation assuring the possibility for individuals and communities to move and communicate, bringing coherence to certain zones development and to the relations among them [1].

Periodically, the city becomes scantier, validating the assumption that life has the property to extend, to invade and to assimilate new territories and environments. From local development centres, towns turned into high accessibility/attractiveness points – spatially connected through transport networks that catalyzed the continuous process of geographic spreading of activities [2,5].

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Transport became an emblem of individual freedom and quality of space. In collective conscience it is the promoter of socio – economical development, reflecting the structural evolution of the society, being the implicit partner of the important mutations induced to entropic and natural environment.

The connections between transport and environment are double, the changes from society life affecting both transports and environment [10,11].

Despite the efforts of the past decades, knowledge of the correlations among accessibility/attractiveness and mobility is still incomplete because of the different sciences that help understanding movement behaviour and mobility effects on spatial processes and also because of the disciplinary barriers and specific meanings given by the different scientific domains [10].

2. Transport networks accessibility

Transport networks might be characterized through the accessibility offered to certain places and areas and also through their distinct properties (connexity, connectivity, homogeneity, isotropy, nodality) giving them autonomy, coherence, permanence and organization [9,10].

Several formulation and measures for the so common concept of accessibility have been proposed in the past 50 years. Even though this concept is frequently used in technical literature its definition is imprecise most probably due to the connections among human activities and the need for mobility. Unanimous specialists opinion is that accessibility must be defined in the context of the interdependence among transportation and human activities system [10,13].

The mathematical approach of accessibility is a notable way to analyze geographically the transport systems. For example, we mention some authors who have dealt with this issue-papers of the theory of graphs and space geography [3,4,6,7,14].

Accessibility might be also perceived as an indicator characterizing the trips to a certain destination, with a certain transport mean, at a certain time and on a certain route. The characterization is also considering costs, travel time and some trip quality indices (comfort, commodity, security, safety, etc.). The travel time, cost and quality indices all together determine a factor called *travel impedance* that must be defeated in order to start and complete the trip. Accessibility is defined as the opposite of impedance [7,14].

Each origin/destination pair belonging to a transport network may have, for each goal, moment and route, some own values of travel time, cost and quality indices, determining the travel array among the two zones.

Accessibility must have different perceptions for the points of interest of travellers or goods. So, the accessibility of the points of interest within centre cities is strongly influenced by the lack of parking lots and by the limited time parking that might discourage a lot of the trips made by own car. In this context, finding a parking place and the parking cost strongly influence the trips impedance and might become determinant elements in establishing the degree of accessibility of a certain area.

In goods transportation, the parking problem is different from the one of personal cars as stationing time for supply might have smaller values and the moment in time can be chosen outside the peak hours. This way, goods transportation interfering with traffic is reduced.

Another problem regarding the trip is the one of residence accessibility, mostly at work time ending or anytime a peak hour trip is achieved. In these conditions the moment in time is uniquely determined by the end of a work day, with variables only the route and the transport mode. In this situation the size of trip impedance becomes significant and must be overcome as it is a trip that must be realized in a certain time interval.

Topologically speaking, the transport networks might be mainly characterized by connexity, connectivity and nodality.

Connexity is a concept with roots in graph theory and shows that within a graph there are no isolated nodes. On a transport network that means that there is no locality that can not be reached, starting the trip from any point. In other words, from any origin point a destination point can be reached. This can be made with just one connexion (just one link) or a path (orientated or not links succession).

The fact that graph's links are orientated or not lead to the concept of strong or weak connexity.

Math defines networks connexity as follows [6,10]: for the R network associated to the S territory system an orientated graph is also being associated, G[R], defined by the $[\rho_{ij}]$ matrix, whose elements are:

$\rho_{ij} = 0$, if the a_j nodes, entrances, do not depend on a_i, exits, and

$\rho_{ij} = 1$, the opposite case.

The R network has strong connexity if for any pair (i,j), with $i \neq j$ we have $\rho_{ij} = 1$ or there are k, l, m, …,s, defined by i and j with $\rho_{ik} \times \rho_{kl} \times \rho_{lm} \times ... \times \rho_{sj} = 1$, meaning there is a path between i and j.

Analyzing Bucharest underground network one can draw the conclusion that it resides connexity property, being able to assure in some cases alternative routes.

Networks connexions reliability is described by another index, connectivity. It defines the entire range of connexions assured by the network within the territory system. If the network is perceived as a net (texture) then connectivity is a net density index [12,14].

A conclusion can be drawn that when the net is denser, network's vulnerability is smaller and the probability of an interruption of a link between any two nodes is also smaller leading to an increased degree of network functioning reliability.

Connectivity is defined by α, γ and β indices.

The definition of connectivity indices α, γ and β starts from the non oriented graph G'[R] with $[\rho'_{ij}]$ matrix (graph and matrix associated to the network) and according to the number of nodes (n+1) and links ($\sum_{i,j}\rho'_{ij}$) the three indices are being defined [9,10] as follows:

$$\alpha = \frac{\text{number of circuites}}{\text{max. number of circuites}}; \qquad \gamma = \frac{\text{number of links}}{\text{max. number of links}};$$

$$\beta = \frac{\text{number of links}}{\text{number of nodes}}.$$

With these relations for a non planar graph:

$$\alpha_{np} = \frac{\sum_{i,j}\rho'_{ij} - n}{\frac{n(n+1)}{2} - n}, \quad \gamma_{np} = \frac{\sum_{i,j}\rho'_{ij}}{\frac{n(n+1)}{2}}, \tag{1}$$

and for a planar graph:

$$\alpha_p = \frac{\sum_{i,j}\rho'_{ij} - n}{2n-3}, \qquad \gamma_p = \frac{\sum_{i,j}\rho'_{ij}}{3(n-1)}. \tag{2}$$

3. Case study

In the case study, the underground network connectivity (α, γ, β indices) was studied both for 2005 and 2009, and also for an expected development situation in 2030, according to the estimations found on www.metrorex.ro.

The novelty degree consists in the fact that in this paper the connectivity indices α, γ and β were determined for the 2009 network and also for the one expected to be functional in 2030. For a relevant analyze of the underground network development values of connectivity indices for 2005 are presented in [16].

According to the relations defined in paper [10] connectivity indices were determined for the moments in time for which the network has been analyzed.

In table 1 Bucharest underground network characteristics are presented. Table 2 contains Bucharest underground network connectivity indices determined for the underground network associated graph, at three moments of time.

Table 1

Bucharest underground network characteristics

Main lines		**Length [km]**	**Number of stations**
M1	Pantelimon – Dristor	29,1	22
M2	Berceni – Pipera	18,9	14
M3	Eroilor – Industriilor N. Grigorescu 2 – Linia de Centura	15,25	15
M4	Gara de Nord – 1 Mai	3,7	4
	Total	66,95	55
Served urban area [km^2]			305
Network density [km/km^2]			0,219

Table 1 shows that M1 is the longest line, representing 43,5% of the network and having a total of 40% of the stations, covering all the six sectors of Bucharest (less stations are in Sector 4 – 1 and more in Sector 3 – 9 stations).

Table 2

Bucharest underground network connectivity indices

Network topological characteristics		**Present network**		**Projected network 2030**
		2005	**2009**	
Number of nodes		10	12	24
Number of links		11	13	30
Connectivity indices	alpha	0.022	0.015	0.021
	gamma	0.2	0.166	0.1
	beta	1.1	1.083	1.25

Analyzing the connectivity indices determined for the three periods of time described in table 2 one can notice that network development at 2009 moment led to all three indices (α, γ, β) weakening. This can be linked to the fact that network development was not achieved strictly to increase *net density* but to extend the line towards the outer ring of Bucharest (Glina).

The development desired for 2030 ameliorates the α index (in comparison to 2009) but the value is the same as in 2005. The γ index has the smallest value of all the three time moments proving that the number of network nodes has increased but the links multiplicity is still defective.

The β index has the greatest value in 2030 but this barely characterizes networks connectivity. The increased ratio between the number of links and nodes is proven but this ratio can not lead to entirely define network's links multiplicity.

As a conclusion, by analyzing the values from table 2, one can say that Bucharest underground network has a reduced connectivity that would not become better by achieving the future development plans.

The underground network nodal accessibility was determined both for 2005 and 2009, considering the network being described by its stations that represent the poles (40 poles in 2005 and 43 poles in 2009).

In figure 1, nowadays situation (2009) and the estimated situation (2030) of the underground network are being presented. In table 3 the accessibility of each sector is determined considering that the subway is the only transport mode used for travelling.

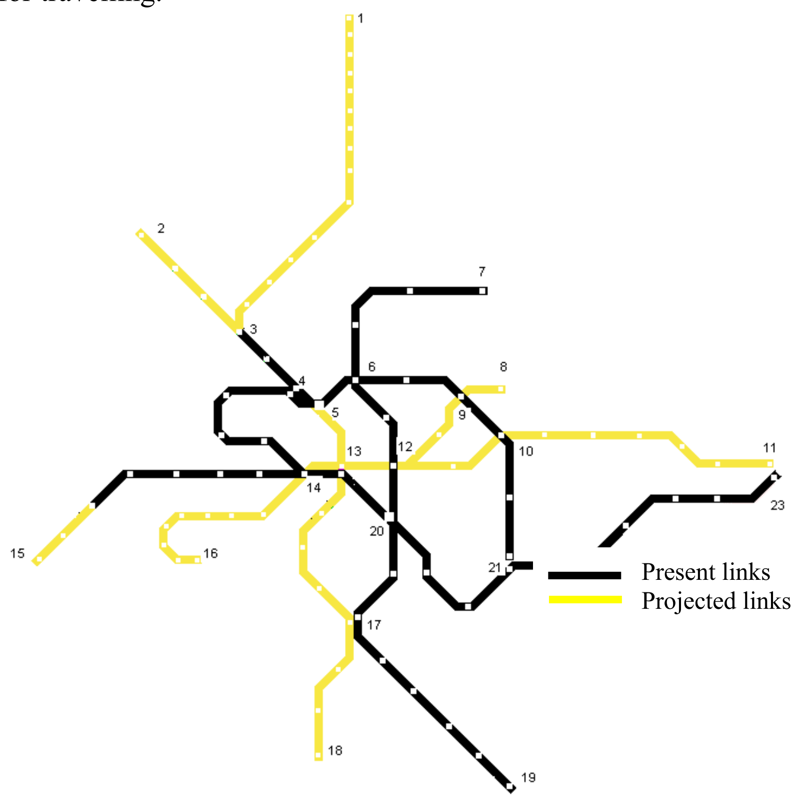

Fig.1. Bucharest underground network associated graph

For each pole of the underground network, 7 comparison criteria were considered:

- NA – number of links with the origin in the considered pole;
- NL – number of transport lines that cross the pole;
- PDA – number of direct accessible poles;
- PIA – number of poles accessible with one interchange;
- PA 15, PA 30, PA 45 – number of accessible nodes in 15, 30 and 45 minutes.

Starting from paperworks [11], [12] and [16] where the values for NA, NL, PDA, PIA and PA 30 were determined for 2005, the present paper determines all the values according to the network's development in 2009 and also PA 15 and PA 45 (table 3). The maximum accepted limit of travel time might have a vast range of answers in relation to trip motivation, context, transport mode service quality, time stability, income, age and some other factors, many being choice subjective. Speciality literature considers a time "budget" daily associated to transportation [8, 15], a restriction an individual can stand (an average of one hour and a half a day, but with a considerable variability).

Table 3

Underground network characteristics in every administrative sector

Index \ Sector		Sect. 1	Sect. 2	Sect. 3	Sect. 4	Sect. 5	Sect. 6
Population [inhabitants]		238217	362609	395565	325000	272305	362877
Population density [inh./km²]		3529,14	11331,53	11634,27	10156,25	9725,18	9549,4
Number of poles 2009		8	4	12	8	3	8
N A 2009		18	7	26	15	7	15
N L 2009		11	4	17	9	5	8
P D A 2009		121	73	266	119	69	130
P I A 2009		172	94	232	210	56	196
PA 15	**2005**	67	27	75	58	33	52
	2009	67	27	100	60	35	57
PA 30	**2005**	188	101	201	163	102	156
	2009	202	112	297	181	114	181
PA 45	**2005**	271	134	306	271	117	279
	2009	288	153	442	300	126	301

For determining these criteria we considered:

I – headway - 6 min;

t_{st} – time lost per stopping at one station - 30 sec;

t_m – station to station average travel time - 3 min;

t_{tr} – transfer time - 6 min.

The time values used in the paper are obtained from underground timetable and circulation books for the time period of the analyze and the transfer time is an average value of line changing. It is obvious that any time value increase would lead to underground poles accessibility decrease.

Fig. 2 illustrates the accessibility of every sector at the two analysed moments.

The maximum reachable number of poles when there is no time limit is n(n+1), where (n+1) is the G'[R] non orientated graph number of nodes.

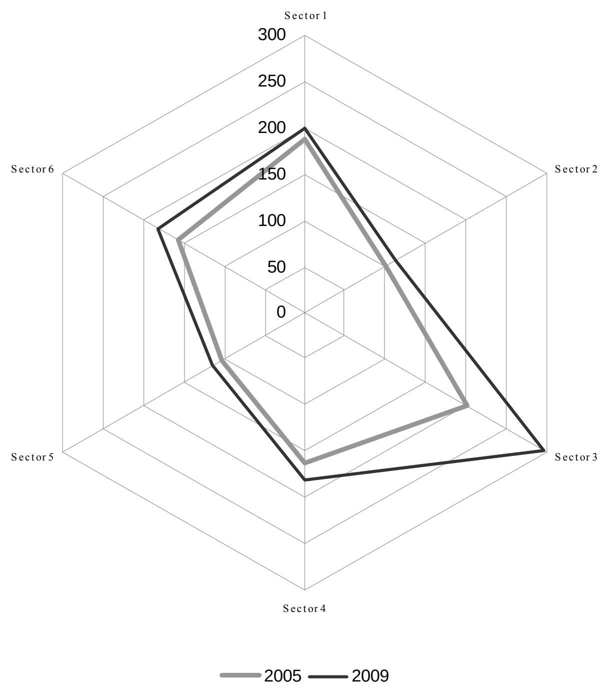

Fig.2. Administrative sectors accessibility – PA 30 (2005 and 2009)

A relative accessibility is being defined as follows:

$$A_{cc}^{(r)} = \frac{n_{pol}}{n(n+1)} \cdot 100 \qquad [\%]$$

The results are concentrated in Table 4.

From table 4 we can notice that for the PA 15 and PA 45 values the difference between the relative accessibilities for the two moments in time has the same value (0,8%) while for PA 30 we get the greatest gap, 1,8%. For the 2009 situation passing from PA 15 to PA 30 would bring a relative increase of 41%, while passing from PA 30 to PA 45 the increase is just of 29%.

Table 4

Relative accessibility

A_{cc} / Index	PA 15		PA 30		PA 45	
	2005	**2009**	**2005**	**2009**	**2005**	**2009**
n_{pol}	312	346	911	1087	1378	1610
$A_{cc}^{(r)}$ [%]	20	19,2	58,4	60,2	88,4	89,2

Regarding these aspects the best underground network accessibility is obtained for a 30 minutes travel time. The graphical representations were achieved only for this value, size degree being unchanged for PA 15 and PA 45.

Figure 3 shows the number of links and lines within the six administrative sectors of Bucharest in the present situation.

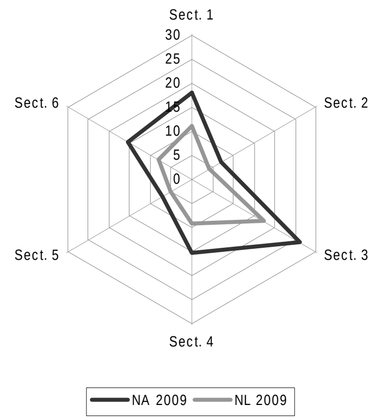

Fig.3. NA and NL situation within the six administrative sectors

The greatest number of links and lines is in Sector 3 (fig. 3), explaining the fact that Sector 3 has the best accessibility.

Figure 4 presents the number of direct and indirect accessible poles within the six administrative sectors of Bucharest.

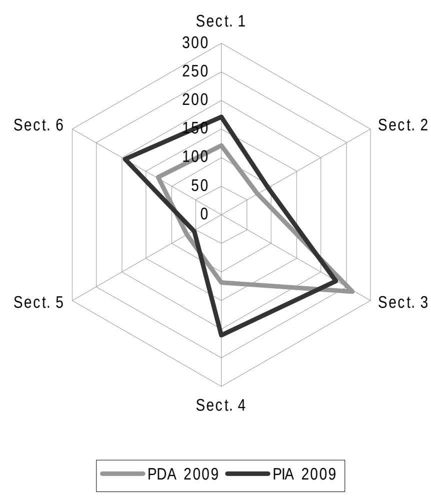

Fig.4. PDA and PIA situation within the six administrative sectors

In the first place we still have Sector 3 followed by Sector 4 (fig. 4). Taking into account that many inhabitants of Bucharest live within Sector 3, a sector with the greatest density, we can consider that the leading position in the rank of accessibility and network development is a fair one.

The correlation between population, its density and the accessibility of the six sectors is presented in Table 5.

Table 5

Correlation between population, its density and the accessibility of the six sectors

Index		Correlation	Regression equation	Coef. R^2	Coef. R	Observations
No. of population	2005	PA 15	y = 215.22x + 314904	0.0045	0.067	Lack of correlation
		PA 30	y = 134.62x + 305656	0.0089	0.094	Lack of correlation
		PA 45	y = 179.19x + 284941	0.0594	0.244	Lack of correlation
	2009	PA 15	y = 656.75x + 288223	0.0794	0.282	Lack of correlation
		PA 30	y = 315.27x + 268979	0.1269	0.356	Lack of correlation
		PA 45	y = 225.88x + 265485	0.1862	0.432	Lack of correlation
Population density	2005	PA15	y = -48.763x + 11857	0.0963	-0.310	Lack of correlation
		PA 30	y = -23.257x + 12852	0.1102	-0.332	Lack of correlation
		PA 45	y = -7.6038x + 11067	0.0442	-0.210	Lack of correlation
	2009	PA 15	y = -7.5314x + 9755.3	0.0043	-0.066	Lack of correlation
		PA 30	y = -0.825x + 9470.4	0.0004	-0.020	Lack of correlation
		PA 45	y = 0.4886x + 9189.9	0.0004	0.020	Lack of correlation

From table 5 one can notice that there is no correlation between the number of population and its density within the six sectors of Bucharest and the different values of accessibility. Among the causes determining the lack of correlation we can mention: lack of underground network development in concordance to the six sectors situation or the great degree of aggregation of the data for the six sectors of Bucharest.

In order to overcome this last inconvenient we considered the Bucharest map divided into 72 homogenous zones from the destination and available utilities point of view, covered by the underground network map [16].

Opposite to [16], the present paper evaluates the accessibility of the 72 zones (PA 15, PA 30 and PA 45) and determines the influence of the underground network on each zone under the aspects of the already defined indexes (NA, NL, PDA, PIA for 2009 level of development).

The analyzed situation is presented in table 6.

Table 6

Underground network characteristics and study areas accessibility

Study area	Pole	Pop. no.	Pop. dens. [inh/Ha]	NA (2009)	NL (2009)	PDA (2009)	PIA (2009)	PA 15		PA 30		PA 45	
								2009	2005	2009	2005	2009	2005
3	Berceni, Dimitrie Leonida	18810	30	3	2	26	56	9	9	19	19	57	51
4	Piața Sudului, Constantin Brâncoveanu	17120	160	4	2	26	56	15	15	42	39	79	70
5	Pantelimon, Republica	38400	75	3	2	40	44	9	9	28	22	59	53
6	Anghel Saligny Nicolae Teclu	0	0	3	2	28	52	9	0	34	0	68	0
8	1Decembrie 1918, Titan, Nicolae Grigorescu	49410	270	7	4	62	62	27	16	74	40	117	72
9	P-ta Unirii	4350	75	4	3	40	2	16	16	41	39	42	39
10	Eroilor	10725	75	3	2	28	14	12	12	36	34	42	39
11	Izvor	8625	75	2	2	28	14	13	11	40	38	42	39
12	Grozăvești, Petrache Poenaru, Crângași	11625	75	6	3	60	66	26	26	91	91	121	113
13	1Decembrie 1918, Nicolae Grigorescu	24300	75	5	3	42	40	19	9	51	22	80	38
14	Eroii Revoluției	2970	30	2	1	13	28	8	8	31	27	42	39
16	Crângași	8100	30	2	1	20	22	9	9	28	28	38	36
19	Timpuri Noi, Pta.Unirii, Mihai Bravu	10425	75	8	7	96	30	39	35	116	106	126	117
20	Crângași	35400	600	2	1	20	22	9	9	28	28	38	36
21	Politehnica, Grozăvești, Petrache Poenaru	18300	75	6	3	54	70	26	24	89	80	125	116
23	Dimitrie Leonida, Aparatorii Patriei, Pta. Sudului	16890	30	6	3	39	84	18	18	43	42	107	93
24	Lujerului	41580	270	2	1	14	26	7	5	22	15	41	38
27	Constantin Brâncoveanu, Pta Unirii, Timpuri Noi, Tineretului, Eroii Revoluției	23325	75	12	8	107	100	54	52	171	152	208	192
30	Pta. Sudului, Constantin Brâncoveanu	28320	160	4	2	26	56	15	15	42	39	79	70
31	Pta Iancului, Obor	9440	160	4	2	40	44	13	13	62	55	78	68
32	Eroii Revoluției, Tineretului	25760	160	4	2	26	56	18	18	67	56	84	78
33	Pța. Muncii	11775	75	2	1	20	22	7	7	31	25	38	33
34	Obor	32320	160	2	1	20	22	7	7	31	27	39	34
36	Pantelimon, Costin Georgian	28500	75	3	2	40	44	10	10	32	25	62	56
37	Pta. Iancului, Obor	48960	160	4	2	40	44	13	13	62	55	78	68
38	Universitate, Obor, Stefan cel Mare	31360	160	6	3	53	72	27	27	101	85	122	109

39	Păcii, Gorjului, Lujerului	53190	270	6	3	42	78	18	15	54	39	111	102
40	Titan, Nicolae Grigorescu, Dristor, Pta Muncii	73760	160	10	6	96	72	42	35	116	93	158	144
44	Universitate, Pta.Unirii	3975	75	6	4	53	30	26	26	79	69	84	78
45	Păcii, Gorjului, Lujerului	38340	270	6	3	42	78	18	15	54	39	111	102
46	Preciziei, Păcii	28050	30	3	2	28	52	9	9	24	20	59	54
47	Pța Muncii, Pța Iancului	9525	75	4	2	40	44	13	13	62	53	77	67
50	Mihai Bravu, Dristor	33280	160	5	4	56	28	26	21	70	60	84	78
52	Pantelimon, Republica, Costin Georgian, Titan	36450	75	7	4	80	88	23	22	70	55	130	118
53	Eroii Revoluției	4500	75	2	1	13	28	8	8	31	27	42	39
54	Pța Muncii, Pta Iancului	24000	160	4	2	40	44	13	13	62	53	77	67
57	Dimitrie Leonida, Apărătorii Patriei, Pta. Sudului	50240	160	6	3	39	84	18	18	43	42	107	93
58	Universitate, Pța Romană	15120	270	4	2	26	56	20	20	70	58	84	78
59	Izvor	15000	600	2	2	28	14	13	11	40	38	42	39
60	Eroilor, Izvor	17440	160	5	4	56	28	25	23	76	72	84	78
61	Gara de Nord, Basarab	9120	160	5	4	44	40	22	22	56	55	81	77
62	Stefan cel Mare, Pța Romană, Pta. Victoriei	8160	160	8	4	65	60	35	35	95	87	125	114
63	Gara de Nord, Pța Victoriei, Basarab	23220	270	9	6	76	50	37	37	87	86	123	116
64	Pța Victoriei, Basarab	24840	270	7	4	54	30	25	25	59	58	81	77
65	Stefan cel Mare, Aviatorilor, Pta. Victoriei	35360	160	8	4	65	60	33	33	90	84	118	106
66	Aurel Vlaicu, Aviatorilor	45075	75	4	2	26	56	13	13	52	48	67	60
67	Grivița, 1 Mai	30825	75	3	2	6	38	7	7	31	26	56	56
69	Stefan cel Mare, Aurel Vlaicu	11025	75	4	2	33	50	15	15	57	51	73	65
70	Basarab, Grivita, 1 Mai	57450	75	6	4	28	58	17	17	59	53	95	94
72	Pipera, Aurel Vlaicu	13320	30	3	2	26	56	9	9	43	41	66	59

A pole on the border between two zones is considered to offer accessibility to the inhabitants of both areas.

Table 6 shows that there are zones with just a pole (11 zones), zones with two poles (23 zones), zones with three poles (13), zones with four poles (2), zones with five poles (1) and other 22 zones that are not served by the underground network (1, 2, 7, 15, 17, 18, 22, 25, 26, 28, 29, 35, 41, 42, 43, 48, 49, 51, 55, 56, 68, 71). As can be noticed a great deal of the zones are not served by underground network.

In table 7 we present a synthesis of the data from table 6 in relation to the number of poles from each zone. The $N_{st/inh}$ index represents the number of poles for an inhabitant within those zones.

Table 7

Number of poles, zones area and population for the study zones

No.	No. of poles in each zone	No. of zones	Zones area [km^2]	Relative area [%]	No. of population	Relative no. of population [%]	$N_{st/inh}$ [x 10^{-5}]
1	0	22	64,67	34	716110	36	0
2	1	11	13,41	7	188282	9	5,84
3	2	23	65,73	35	543665	27	8,46
4	3	13	32,58	17	435442	22	8,96
5	4	2	9,47	5	110210	5	7,26
6	5	1	3,11	2	23325	1	21,44

From Table 7 one can easily notice that 34% of the city area and 36% of the population from the studied zones have no access to the underground network as in 22 of the zones there are no metro stations. These zones are placed in Drumul Taberei, Ghencea, 13 Septembrie, Rahova, Ferentari, Pantelimon, Colentina, Floreasca districts. Following the analysis, the network should be developed mainly in these areas and not like the last expansion that took place in Sector 3, already having a good accessibility for the underground network. We must state the an accentuated expansion on the network in the zones already having underground network leads to accessibility increase and as a consequence to land and apartments price increase knowing the fact that a better accessibility towards city centre leads to assets market value increase. An equilibrium brake might appear between different zones development that could bring high population concentration in the areas with increased accessibility, with consequences on transport quality within urban area.

The $N_{st/inh}$ index has the best value (much superior to the others) in a zone with five underground stations and a number of populations relatively low (zone 27).

Fig. 5 shows the correlation between population within the study zones and PA 30 accessibility for 2009 situation while figure 6 presents the correlation between population density and the same PA 30 accessibility.

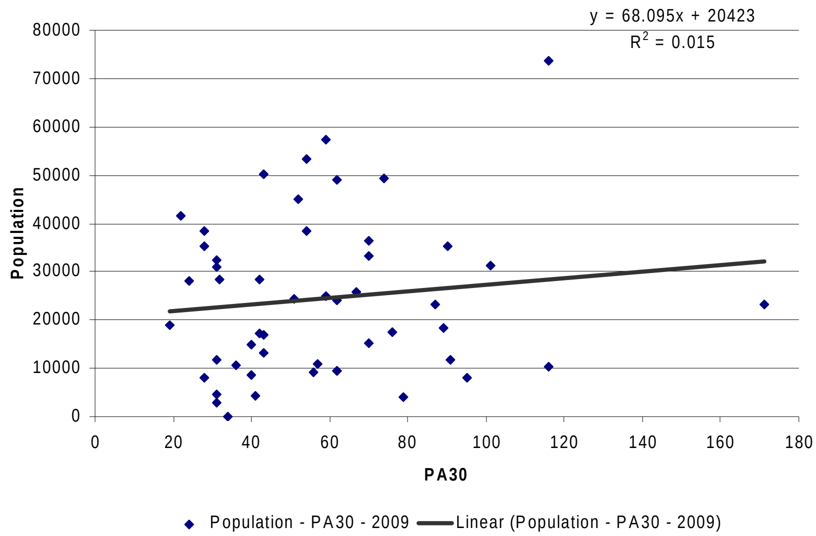

Fig. 5. Zones population – level of PA 30 accessibility correlation (2009)

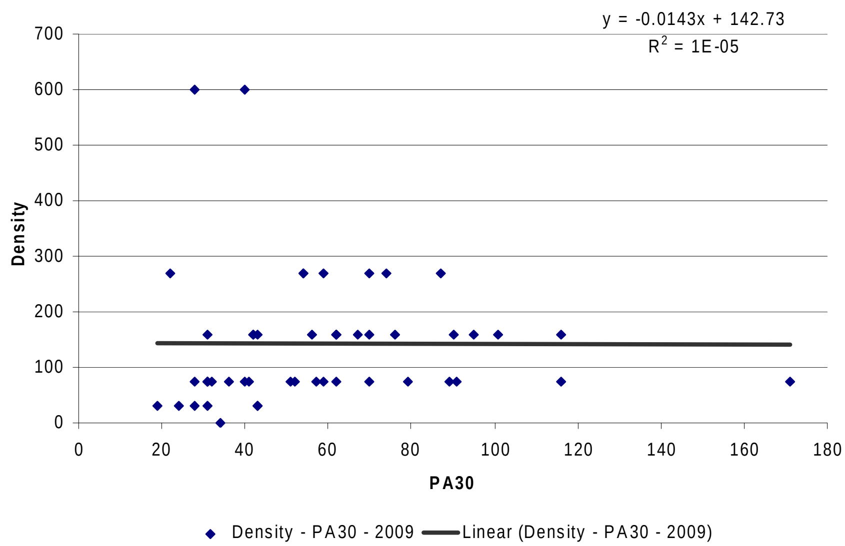

Fig. 6. Population density – level of PA 30 accessibility correlation (2009)

As anyone can notice the two charts prove that there is no correlation between population, population density and the considered accessibility, drawing the conclusion that Bucharest underground network has not been developed according to population situation and further studies are necessary to harmonize network's development and the city's development tendencies and urbanism politics.

4. Conclusions

Many definitions have been proposed for the concept of accessibility over the years, all of them trying to define access by minimizing the distance, travel time, cost or easiness of defeating and accepting a movement resistance function (deterrence function!). From the accessibility point of view, defined as easiness of reaching space separated points but connected by a network of any kind, accessibility notion remains limited and even imprecise.

Defining accessibility for any nature networks was achieved by engineers, mathematicians, economists, geographers, land use planners that could not yet reach a common formulation probably because of the its abstract aspect and belonging to the less defined framework of interaction between human activities system and the transportation one.

Difficulties also appear because of the different ways that the two systems are treated and perceived by specialists with different formation involved in studying networks, leading not always to compatible interpretations but to confusions, even for the terminology.

The definition of accessibility might also include network's vulnerability that might be bettered by increasing the *net density* within network's structure. Connectivity indices α, γ and β are the ones that could be used, with a certain weight, to determine places' accessibility. The first two very well characterize connectivity, the last one being more a network development degree index.

Analyzing the underground network connectivity indices at three moments of time, it can be concluded that the resulted values are small both in the present and in the future, because the public authority is orientated to the extension of the network towards the Bucharest adjacent villages and not to the multiplication of the existent links.

Sector 3 that held the first place in 2005 consolidated its position, gaining a lot in comparison with the other sectors. This is normal considering that the underground network extended with three stations in Sector 3.

Underground network development in Sector 3 (towards Glina) was achieved as a result of Urbanism Development Plans existing before 1989, because at that moment that area was residing heavy industry (Pharmacy Plant, Glass Plant, Policolor, Chemical Plant, RATB dockyard and garage, RATB High school). Now, many of these plants do not exist anymore and the ones still existing have less activity (fewer employees) and are not an attraction pole of Bucharest. It seems that the new line was finalized only because the project and work had been already started and had to be brought to an end, but the correlation with the zone attractiveness was not made and the investment utility is still a discussion subject.

Analyzing the accessibility – population and the accessibility – population density correlations by aggregating the data to the level of administrative sectors and also for the 72 zones homogenous from the activity within point of view, a conclusion appears: there is no correlation.

In conclusion, according to the accessibility values, the underground network must be developed in Sector 2 and in Sector 5.

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