

# Road Traffic development on the penetrating arterial in the municipality of Bucharest

M. Nicolau

*APDP, Bucharest, Romania*

I. Molan

*CESTRIN, Bucharest, Romania*

**ABSTRACT:** The motorization rate in the City of Bucharest, the capital of Romania, was in 2002 of 292 vehicles per 1000 inhabitants, 66 percent higher than the average motorization rate for the whole country. Besides the local traffic the City of Bucharest is a significant center of origin and destination traffic, as well as the major road nodal point for the international and national transit traffic. Under these circumstances the penetrating/exit arterial have to meet a great and ever growing road traffic demand. The limited capacity of this arterial determines the frequent traffic congestion during the peak hours. The paper presents the traffic development on penetrating arterial during 1990-2000 as well as the traffic forecast until 2020 and some actions to be taken for the traffic organization and the increase of traffic capacity.

**RÉSUMÉ :** Le taux de motorisation pour Bucharest, la capitale de la Roumanie était, en 2002, d'environ 292 véhicules par 1000 habitants, 66% plus grand que le taux moyen de motorisation pour le pays. Outre le trafic local, Bucharest est un centre polariseur de trafic d'origine et de destination ainsi que le principal noeud routier pour le trafic de transit international et interne. Dans ces conditions, les artères de pénétration/sortie doivent faire face à une importante et en continue croissance demande du trafic routier. À cause de la capacité limitée de ces artères on produit de fréquents congestions de la circulation dans les heures de pointe. Le rapport présente l'évolution du trafic sur les artères de pénétration pour la période 1990-2000 et la prévision de trafic jusqu'à 2020, ainsi que une série des mesures qu'ils doit être prises pour l'organisation de la circulation et l'accroissement de la capacité de circulation.

## 1 INTRODUCTION

The Bucharest Municipality is the capital and the most important town of Romania. Bucharest has a population of 2 millions inhabitants, representing 9 percent of the total population of Romania and an area of 238 km<sup>2</sup>; the density of population is 8390 inhabitants/km<sup>2</sup>.

The civil employment at the end of 2001 was of 736 thousands persons of which 655 thousands employers.

Bucharest realizes 21% of the Gross Domestic Product and the GDP/inhabitant is 2.07 time greater than the average for all the country.

After 1989, the explosive growth of motorization and traffic, along with an insufficient street maintenance and improvements and a limited capacity of transport generated a deterioration of traffic conditions and frequent road traffic congestion during the peak hours.

Besides the local traffic, the City of Bucharest is a significant center of origin and destination traffic as well as the major road nodal point for the

international and national transit traffic. It is to note that Bucharest is the starting point of nine national roads of which five are European highways (E roads) and a road nodal point for Pan European IV and IX transport corridors.

The future extension in Romania of the Trans European Road Network (TEN R), as is shown in Figure 1 will increase the importance of Bucharest as highway node. Under these circumstances the penetrating/exit arterial of the Bucharest Municipality have to meet a great and ever growing road traffic demand.

## 2. TRANSPORT SYSTEM

The important components of urban transport system to satisfy the transport demand are as follows:

- Transport infrastructure;
- Road Vehicle fleet;
- Traffic characteristics;
- Private transport;

- Public transport;
- Traffic accidents.

Table 3. Evolution of the vehicle fleet in Bucharest Municipality\*

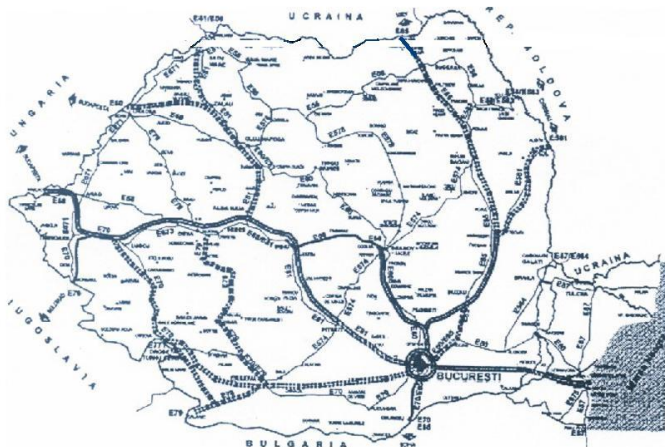


Figure 1. TEN R extension in Romania

### 2.1 Transport infrastructure

The Bucharest transport infrastructure is composed of the surface transport network and the underground transport network.

The long-term planning of underground network construction provides a final length of 147 km of urban metro out of which 45% is under operation.

The surface transport infrastructure is represented by the urban road system. The Bucharest urban road system is of radial-concentric type with radial main streets and two interior rings (medium and central) and an outer ring. The street length is 1821 km of which 838 km with modern surfacing.

The streets are separated in four categories depending on function in the road system and traffic category (Table 1).

Table 1. Street classification

Street category	Functional category	Traffic category	Number of lanes
I	Main street	High intensity	6
II	Trunk street	Intense	4
III	Collector street	Mean	2
IV	Local street	Low and very low	1

### 2.2 Road vehicle fleet

The road vehicle fleet evolution at the national level and for Bucharest Municipality, for 1990-2002 period, is illustrated in the tables 2 and 3.

Table 2. Evolution of the national road vehicle fleet

Year	1990	1995	1997	2002
Total fleet (million vehicles)	2.17	3.36	3.87	4.19
Car fleet (million vehicles)	1.29	2.20	2.61	2.97

Thousands vehicles

Year	1990	1996	1997	1998	1999	2000	2001	2002
Total fleet	346.3	513.5	538.3	564.0	592.7	617.7	651.7	681.0
Cars	252.5	396.8	419.7	443.7	460.3	491.1	520.4	542.3
Buses	3.7	4.0	3.9	3.8	4.4	3.7	3.7	3.7
Goods vehicles	42.1	62.4	64.8	68.2	78.1	73.0	75.9	81.2
Other vehicles types	47.0	50.3	49.9	48.3	49.9	49.9	51.7	53.8
Coefficient evolution	1.00	1.48	1.55	1.63	1.71	1.78	1.88	1.97

\* Plus Ilfov county

Based on the comparison between the vehicle fleet evolutions for Bucharest Municipality and for the entire country, it results as follows:

- for the 1990-2002 period, the annual average rate for the total number of vehicles:
  - 5.6% for the entire fleet;
  - 5.8% for the Bucharest Municipality fleet;
- for Bucharest Municipality by intermediate period:
  - total vehicles for the 1990-1997 period: 6.5%
    - total vehicles, for the 1997-2002 period: 4.8%;
    - total vehicles, for the 2000-2002 period: 5.0%;
    - cars, for the 1990-1997 period: 7.5%;
    - cars, for the 1997-2002 period: 5.3%;
    - cars, for the 2000-2002 period: 5.1%.

The motorization rate in 2002 was 292.2 vehicles per 1000 inhabitants for total vehicles and 232.7 cars per 1000 inhabitants, 66% respective 77% greater than the motorization rate for the whole country.

### 2.3 Road traffic characteristics

The average volumes of traffic expressed by Annual Average Daily Traffic (AADT), in PCU/24 h, by street categories are presented in the Table 4.

Table 4. Average AADT by street category

(PCU/24 h)

Traffic category	Street category			
	I	II	III	IV
Highly intense	50400	28800	12000	Variable depending on surfacing type
Intense	40300	23000	9500	
Mean	22000	12500	5000	
Low	8000	4600	1900	
Very low	2500	1400	600	
Circulation speeds (km/h)	35-40	30-40	25-30	5 on earth surfacing 10 on stone surfacing 20 on asphalt surfacing

The average traffic structure according to street categories and type of vehicles are presented in the Table 5.

Table 5. The average traffic structure

Structure type	Share according to vehicle type %					
	Street category	Motorcycles	Light vehicles	Buses, trolley buses	Goods and special vehicles	
					Medium vehicles	Heavy vehicles
1	I+II+III With heavy traffic	0.1	89.5	2.0	4.4	4.0
2	I+II+III Without heavy traffic	0.1	96.5	2.1	1.2	0.1
3	III*+IV	0.2	99.5	0	0.3	0

\* Streets of the III-rd category with river stones, crushed stone, ballast, earth.

The traffic structure was differentiated on 5 types of vehicles, which are considered for the design of the pavements, for the street traffic capacity calculations as well as for the rate of return analysis of the road investments, that is:

- Motorcycles and mopeds;
- Light motor vehicles: cars, minibuses, vans;
- Public transportation motor vehicles: buses, coaches, trolley buses and maxi taxi;
- Medium-sized goods transportation vehicles, i.e. 2-axle trucks and derived vehicles, having total weights higher than 3.5 t and payload of maximum 10 t;
- Heavy goods transportation vehicles, i.e. 3-4 axle trucks and derived vehicles, road trains and articulated vehicles.

In order to determine the design traffic, in view of designing the street modernization and rehabilitation works and to estimate the degree of utilization of their traffic capacity, the vehicle unit traffic (real vehicles) are equated as traffic of standard design vehicles.

In Romania, the vehicles used as standard vehicles, according to the in force technical provisions, are:

- the standard 115 kN axle for the design of the pavement structure and reinforcement layers;
- the passenger car unit (PCU) for traffic capacity calculations.

The coefficients used to equate as standard 115 kN axles are established by AND-CESTRIN and are included in the AND 584-2002 Norm.

Table 6. Average coefficients used to equate the vehicle units in 115 kN axles

Types of road structures	Vehicle group				
	2-axle trucks and derived vehicles	3 and 4 axle trucks and derived vehicles	Articulated vehicles	Buses	Trailers
Flexible and semi-rigid	0.4	0.6	0.8	0.6	0.3
Reinforcement of flexible and semi-rigid pavement	0.3	0.8	0.9	0.6	0.2
Rigid	0.3	3.8	2.9	1.5	0.2

Coefficients used to equate the vehicle units to passenger car units (PCU) for the streets are complying with SR 7348/2002.

Table 7. Coefficients used to equate the vehicle units to PCU-type vehicles

Crt. No.	Vehicle unit group	Coefficient
1	Bicycles, motor-bicycles, motor-scooters, motorcycles	0.5
2	Cars, with/without trailer	1.0
3	Trucks and derived vehicles, buses	3.5
4	Articulated road vehicles, tow trucks with trailers	4.0
5	Tractors and special vehicles	3.0
6	Trailers towed by trucks or tractors	1.5
7	Trolley buses	4.5

#### 2.4 Private transport

As consequence of motorization growing the weight of the movement of people by car is on continuous increase and at present it represents 20% of total daily trips. The car traffic represents over 90% of total traffic in Bucharest.

The forecast of private road transport until year 2015 estimates:

- car ownership of 350 cars per 1000 inhabitants;
- two strategies of road urban transport development:
  - development unlimited of private transport, "Passenger Car Strategy";
  - development of public transport and nonmotorized traffic and reduction of passenger car "Public Transport Strategy";

- for "Passenger Car Strategy" are estimated:
  - movement of people by car: 45% of total daily trips;
  - annual average increase rate of car traffic: 5.7%;
- for "Public Transport Strategy" are estimated:
  - movement of people by car: 25% of total daily trips;
  - annual average increase rate of car traffic: 2.1%;

## 2.5 Public transport

The means of transport used for public transport in Bucharest are as follows:

- Buses;
- Trolley buses
- Tram
- Light rail rapid transit
- Metro
- Maxi taxis

The evolution of public transport vehicle fleet and of number of passenger transported by public transport system are illustrated in the Table 8 and 9.

Table 8. Evolution of public transport vehicles fleet

Year	Tramcar	Bus	Trolley-bus	Metro-van
1991	844	1200	261	468
1992	844	1223	257	486
1993	844	1216	253	498
1994	896	1239	247	500
1995	796	1268	270	502
1996	802	1222	268	502
1997	812	1606	265	502
1998	825	1369	290	502
1999	745	1800	281	502
2000	610	1450	274	502
2001	610	1353	274	502

Table 9. Evolution of public transport

Year	Inhabitants (millions)	Millions passengers transported			
		Tram	Bus & Trolley bus	Metro	Total
1991	2.107	267	361	244	872
1992	2.066	346	400	207	953
1993	2.067	284	385	172	841
1994	2.061	253	354	173	780
1995	2.054	249	336	164	749
1996	2.037	254	346	157	757
1997	2.028	333	443	148	924
1998	2.016	326	433	111	870
1999	2.011	337	448	109	894
2000	2.009	384	469	105	958
2001	1.997	388	475	102	965

The annual fluctuations in vehicle fleet were due to the renewal of the old fleet.

After 1996 the important and repeated rise of the price of fuel produced an negative impact on private transport and an increase of utilization of public transport means.

## 2.6 Traffic accidents

A traffic accident dynamic assessment emphasizes a trend of continuous decrease of the accident number, and of the injures and dead number.

The number of accidents decreased as a result of the measures taken both to regulate and discipline the road traffic, and to improve the road signaling.

The Table 10 shows the evolution of the serious traffic accidents, all over the country.

Table 10. Traffic accident dynamics within the 1995-2002 period

Year	Thousand accidents							
	1995	1996	1997	1998	1999	2000	2001	2002
Serious accidents	9.119	8.931	8.801	8.457	7.846	7.555	7.244	6.906
Dead	2.877	2.863	2.845	2.863	2.778	2.505	2.499	2.461
Seriously injured	7.698	7.504	7.451	7.221	6.594	6.315	5.963	5.649

The table 11 shows the evolution of the number of serious accidents within the 1997-2002 period in Bucharest City.

Table 11. Serious traffic accident dynamics in Bucharest Municipality

Year	1997	1998	1999	2000	2001	2002
Serious accidents	1214	1180	1090	792	772	707
Dead	256	266	243	103	121	85
Seriously injured	1087	1056	963	734	708	656

For the 1997-2002 period the annual average rates as for the traffic accident number decrease were as follows:

For the entire public road network:

- ◆ 5.0% for the total number of serious accidents;
- ◆ 5.7% for the number of seriously injured;
- ◆ 4.0% for the number of dead.

For Bucharest Municipality:

- ◆ 11.4% for the total number of serious accidents;
- ◆ 10.6% for the number of seriously injured;
- ◆ 24.7% for the number of dead.

One can notice that the traffic accident decrease rate for Bucharest City is 2 times higher than the rate

corresponding to the entire country, while the decrease rate of deceased resulting from accidents is 6 times higher than the same rate for the entire country.

### 3. ROAD TRAFFIC EVOLUTION ON PENETRETING ARTERIAL

Bucharest is the starting point of 17 roads of which a motorway (A1), 8 national roads and 8 county and communal roads (Table 12).

Table 12. Penetrating roads in Bucharest

Nr. crt.	Road number	E number	Direction
1	DN 1	E 60	Otopeni-Ploiești
2	DN 2	E 60,E 85	Afumați-Urziceni
3	DN 3	-	Brănești-Constanța
4	DN 4	-	Orăști-Oltenița
5	DN 5	E 70, E 87	Călugăreni-Giurgiu
6	DN 6	E 70	Bragadiru-Craiova
7	DN 7	-	Chitila-Pitești
8	A 1	E 81	DJ 601-Pitești
9	DN 1A	-	Buftea-Ploiești
10	DJ 200B	-	Săftica
11	DJ 200	-	Ștefănești
12	DJ 301	-	Cernica
13	DJ 401	-	Berceni
14	DJ 601	-	Dragomirești
15	DJ 602	-	Domnești
16	DC 5	-	Tunari
17	DC 18	-	Măgurele

Besides in the next period the number of penetrating arterial will increase with two motorways:

- A2 Bucharest-Constanța;
- A3 Bucharest-Ploiești.

The origin of the eight national roads, of which five are European roads (E roads) is in the center of the city.

The penetrating arterial in Bucharest is shown in the scheme from Figure 2.

The traffic evolution on penetrating roads from 1990 till 2000 and the forecast until 2020 is shown in Table 13. In the Table 13 are also included the values of design capacity for each road and are underlined the years when the traffic exceeds the capacity.

For the whole network of penetrating roads the daily road traffic volume evolution is presented in Table 14.

One can notice that beginning with 2005 the total traffic exceeds the design capacity of the whole network of penetrating roads.

Table 13. Traffic evolution and forecast on penetrating road  
Period 1990-2020

Road number	AADT Thousand/PCU/24h						Design capacity
	1990	1995	2000	2005	2010	2020	
DN 1	22.8	29.3*	51.2*	65.5*	85.1*	115.2*	26.4
DN 2	13.5	18.4	27.9*	35.4*	45.5*	61.6*	26.4
DN 3	9.0	11.6	18.8	23.5	30.3*	40.6*	26.1
DN 4	6.5	11.0	10.9	13.6*	17.4*	23.4*	13.0
DN 5	23.7*	22.1	30.6*	37.4*	47.0*	64.3*	22.5
DN 6	31.2*	20.9	21.3	26.4*	33.5*	45.5*	21.6
DN 7	15.4	10.0	19.2	23.2*	30.0*	40.1*	21.6
A 1	20.5	27.9	18.9	24.0	31.0	42.1*	30.7
DN 1A	17.6*	19.8*	20.8*	24.6*	31.4*	41.8*	13.0
DJ 200B	-	-	7.0	8.7	11.0	12.9*	11.4
DJ 200	2.5	4.7	3.8	4.7	5.9	7.9	11.4
DJ 301	3.7	3.4	4.0	4.9	6.1	8.1	11.4
DJ 401	10.6	7.5	5.7	7.2	9.2	12.2*	11.4
DJ 601	-	4.7	3.9	4.9	6.2	8.3	11.4
DJ 602	2.5	3.2	3.3	6.5	8.1	10.8	11.4

\* Exceeding the design capacity

Table 14. Daily road traffic volume on all penetrating roads in Bucharest

Year	AADT Thousand PCU/24h	Trend Base year 1990
1990	180	1.00
1995	215	1.19
2000	248	1.38
2005	310*	1.72
2010	398*	2.21
2020	536*	2.98
Design capacity	270	-

\* High than design capacity

The design capacity values have been determined according to level of service D for roads with two lanes and to level of service C for roads with four or six lanes and for motorway.

In order to diminish the traffic congestion on the arterial and to limit the town crossing by the transit traffic, the major short- and medium-term steps that have to be taken for the traffic organization and the increase of the traffic capacity are, as follows:

- increasing of the traffic capacity and completion of the inner ring roads in the City of Bucharest;
- rehabilitation and increasing of the traffic capacity of the existing outer ring road of the City of Bucharest;
- construction of a new outer ring, as a motorway, in order to link the motorways and national roads penetrating in the City of Bucharest;



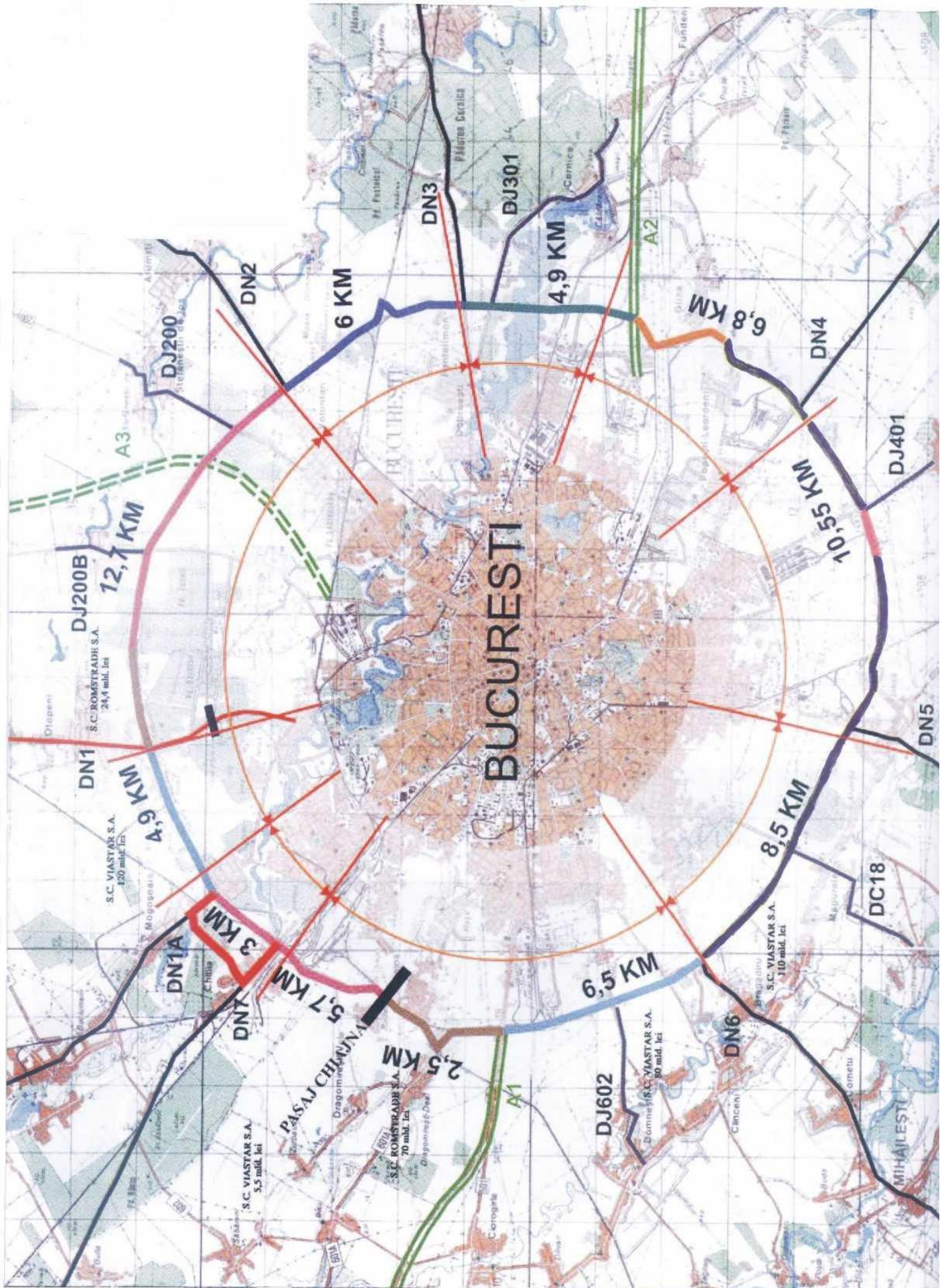


Figure 2. Penetrating roads in Bucharest

- increasing of the traffic capacity of the existing penetrating national roads;
- construction of two new motorways:
  - Bucharest-Fetești-Constanța motorway, on corridor IV;
  - Bucharest- Ploiești motorway, as first section of the Bucharest-Brașov-Cluj-Borș and Bucharest-Buzău-Albița motorways, on corridor IX.

#### 4. CONCLUSIONS

Bucharest, the capital of Romania, is the biggest and most important town of the country. Today its transport system is in a renewal and modernization process. The limited traffic capacity of the urban road network determines frequent traffic congestion during the peak hours.

Because Bucharest is a major road nodal point for international and national traffic the transit traffic superposed over the local traffic has an important contribution to traffic congestion.

The analyze of the traffic evolution for the period 1990-2020 on penetrating road in Bucharest pointed out that until 2005 on the most part of sections of national road penetrating in Bucharest the traffic will exceed the design capacity.

In order to diminish the traffic congestion on the penetrating arterial and to limit the city crossing by the traffic transit short and medium term measures have to be taken as follows:

- on short term rehabilitation and increasing of the traffic capacity on the outer and inner ring roads;
- on medium term construction of the motorway ring in order to link the motorways and national roads around Bucharest.

#### REFERENCES

1. xxx Detailed Study on the urban transport in Bucharest City and its metropolitan area. Japan International Corporation Agency (JICA), Bucharest, 1999.
2. xxx Project for the rehabilitation of Bucharest Municipality's urban roads. Traffic Study. SPEA and CONSIT SA, Bucharest, 2002.
3. xxx Project for the rehabilitation of Bucharest urban roads. Maintenance Strategy. Main Report, SPEA, Bucharest, 2002.
4. xxx Feasibility study for the rehabilitation of Bucharest's streets. Traffic Study. ROMAIR CONSULTING, Bucharest, 2003.
5. Technical norms on the design and construction of urban locality streets. Order of the Ministry of Transport no. 49/1998.
6. Index AND 584-2002. Technical norms on evolution of design traffic for the pavement and traffic capacity design.
7. SR 7348/2002. Vehicle equivalents meant to determine traffic capacity.

8. STAS 10144/3-91. Street geometric elements. Design provisions.

9. STAS 10144/5-89. Calculation of the street traffic capacity.

10. xxx Serious traffic accident dynamics. Road Police Department, the 1990-2002 period.

11. xxx Vehicles registered for road circulation and number of road traffic accidents. National Statistics Institute, the 1990-2003 period.