URBAN AND PERI-URBAN PASSENGER TRANSPORT INTEGRATION THROUGH HUB-AND-SPOKE-NETWORK

Valentin CÂRLAN
University POLITEHNICA of Bucharest, Splaiul Independentei 313, Bucharest, Romania
valentin_carlan@yahoo.com

Eugen ROŞCA
University POLITEHNICA of Bucharest, Splaiul Independentei 313, Bucharest, Romania

Mircea Augustin ROŞCA
University POLITEHNICA of Bucharest, Splaiul Independentei 313, Bucharest, Romania

Abstract
Nowadays sustainability is among the most desired characteristics of the transport systems. Taking into account the soaring and the unpredictable rise of the transport needs in urban areas, in contrast with the suggestions for reducing individual travels, new solutions which should integrate the transport resources both of urban and suburban areas must be sought. The idea of organizing freight distribution chains through hub-and-spokes network can also be adapted for passengers transport. The infrastructure for individual transport, whenever motorised or non-motorised modes, in the proximity of large cities should also be developed to serve other high capacity transport networks, accomplishing all the traveller's needs within the sustainability framework. The technical, administrative or financial integration of peri-urban transport modes with urban public transport is a key element. The current paper highlights the particularities of such an approach and presents a case study for reorganizing the urban and peri-urban connections in Bucharest city.

Keywords: sustainable transport, transport modes integration, urban and peri-urban transport, hub-and-spokes network.

1. INTRODUCTION

Sustainable development is guided by the balance between three main issues which each system must overcome: economic, social and environmental. The Brundtland Report (WCED, 1987) defined the sustainable development as „the development that meets the need of the present without compromising the ability of future generation to meet their own needs".

The transport sector has always shown a steady growth in terms of provided activities (volumes and traffic). This growth is supported primarily by the logarithmic scale of the average daily trip length. In France the average distance of the daily travel (excluding walking distances) was less than 100m in

1800, about 1km in 1900 and increased to 50 km from the late 20th century (Grubler, 2004). Both the growth of number of provided services and the constant rise of the trip length is just a consequence of two overlapping issues that evolution of urban and peri-urban space is facing:

- the expansion of cities outskirts;
- the delayed reaction of transport systems to the dynamic needs of the residents.

The individual motorized transport has a great share in the present transport options and to hold down this trend, measures to increase the attractiveness of the public transport system must be adopted (European Commission, 2007).

Over the time, a series of new measures were done in order to increase the performances of public transport system: new transport lines were created, timetable of different means of transport were correlated, the operating fleet was dimensioned accordingly to the population density and access restrictions were imposed to different areas of the cities.

Urban and peri-urban residents generally choose, as a form of transport, the mean which is more facile to their individual needs for mobility. This subjective preference often brings them in overuse of individual transport forms with significant social and environmental negative impacts. Therefore the transport means integration, the cooperation between different transport operators and the use of non-motorised travel means can be exploited for an efficient use and advantages for every market actor:

- Non-motorized transport (zero emissions, low capacity and short autonomy);
- Individual motorized transport (high emissions, low capacity, long range);
- Mass transportation (medium emissions, high capacity, long range).

In addition to the benefits of integrating all modes of transport, it should overcome a series of problems created by the use of some transport means for specific zones: territory segregation and fragmentation by the mass transport or weather dependence of some green modes. The cooperation between all involved actors is a central element on which relies the success or the failure of the integration which should aim for quality increase of the transport service and a reliable treatment of the users (James, 2001).

The common institutional barriers in adopting and implementing a sustainable transport policy are highlighted by Banister (2005):

- Resource barriers – local, regional, and governmental authorities are reluctant to provide money for investments that do not match their policy priorities;

- Institutional – the inner structure of institution involved in transport provision and the differences in culture between departments (e.g. bureaucratic, market oriented, sustainable vision), the lack of coordination and the dissipation of legal power may reduce the capacity to implement;
- Social and cultural – social acceptability is often influenced by the type of implementing measures (push or pull actions), the pull (encouragement) measures being more popular than push (discouragement) measures;
- Legal – many transport policies need adjustment of laws and regulations outside the transport domain, therefore more efforts have to be done in implementing them;
- Side effects – sometimes is quite difficult to anticipate both positive and negative side effects (e.g. road pricing, traffic calm), but former records on their utility gathered from other areas could help in choosing the most suitable policy;
- Physical – the topography of the area may limit the implementation of the policies (e.g. slope terrain, narrow spaces, and land fragmentation).

2. MULTI MODAL INTEGRATION

The characteristics which improve the efficiency of hub-and-spokes networks is the cost reduction, negative emissions decrees and both the scale and density effect generated in the network (Raicu and Raicu, 2003). Based on the success which this kind of network management brought for freight transport (Raicu and Raicu, 2003; The Netherlands TRAIL Research School, 2006), the passengers transport could also benefit, air transportation being the first which used this kind of organization (Denis, 1994; Button, 1999). The diversity of terrestrial transport ways for people can offer a wide range of combinations so that the high capacity transport means can offer an efficient connection between hubs.

The territory is limited in terms of its ability to accommodate different activities, and not many activities can be developed and deployed inside a given area without creating a transport connection to each type of activity. As an example, the development of a large commercial area without reliable connections to residential areas is considered useless. The urban planning outlines two kinds of visions for the development of urban spaces (Rebelo, 2012). Firstly, many urban planners are suggesting that an urban space should be developed in a multi-purpose way with services that should cover all of the residence's needs (e.g. industrial, study, commercial, residential and recreational spaces). This kind of spatial organisation does not need a high capacity transport service but one categorized as flexible. On

Theoretical and Empirical Researches in Urban Management
Volume 9 Issue 1 / February 2014

the other hand another suggestion made by urban planners is that an urban space should be crumbled away as different larger zones characterized by a single main activity. This kind of development needs a high capacity transport service to provide direct and reliable connections among zones. But the relevance of the two solutions for any present urban area is very low because many urban cities have reached their maturity and changes cannot be done easily. Even though, the two ideas cannot be individually applied, a hybrid model with elements from each side is more appropriate and increases the connectivity without harming the sustainability of already mature urban zones, by using the benefits of hub-and-spokes networks. The purpose of this kind of organization is to serve a large urban area by a reliable transport network which will integrate together both mass transport and individual ways of travel.

Another solution that supports transport sustainability is to reduce the number of single purpose travels by doing a multi-purpose journey. The transport system should be designed to offer a range of services inside its terminals and during the period between intermodal changes, travellers might have access to business, commercial, medical or leisure services. This new concept is widely used for the design of the new transport terminals (e.g. Westbahnhoff - Vienna, Kamppi Centre - Helsinky). Thus the hubs can be upgraded to more complex interchange points which, beside modal split facilities, should also offer a wide variety of services in figure 1. The benefit of an integrated development is justified by cutting resource consumption and decreasing of the travel time. This approach leads to a new transport flows modelling, each node being considered as having a more complex structure (Raicu et al., 2007).

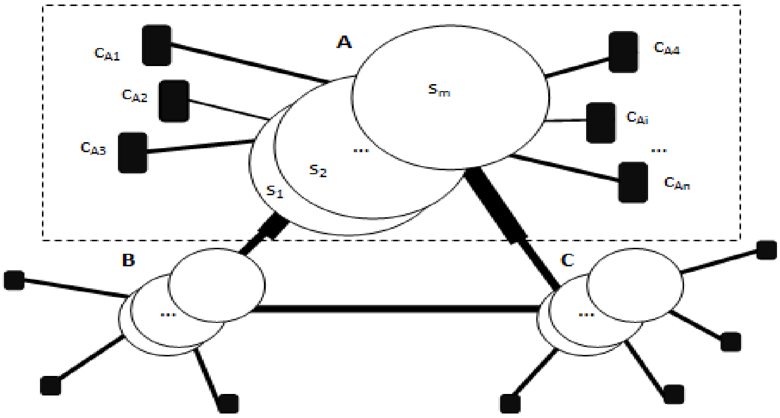

FIGURE 1 - A HUB-AND-SPOKES NETWORK WITH NON-HOMOGENEOUS HUBS

Notes:
A,B,C – multi-service hubs;
Sm – services offered in hubs;
cAn – local origin and destination centres.

The literature related to hub-and-spokes networks emphasises that there are two main categories of problems which passenger transport is facing: firstly, the establishment of hubs and secondly, the organisation of the transport flows over the network (Campbell, 1994; Campbell, 2002; Alumur and

Kara, 2008; Yang, 2009; Contreras et. all, 2010). These problems become even more difficult when a multi-active development of hubs is aimed.

The final goal of integrating in a non-competitive way each transport mean cannot be done without the development of the interchange points. This achievement will encourage travellers to abandon their personal vehicles in favour of the public transport for their onward urban journey. GART (Groupement des Autorités Responsables de Transport) defines passenger interchange points to be the facility that employs at least two modes of public transport or at least two different locomotion means and facilitate intermodal transport practices, in order to materialize and optimizing the relationship between these involved modes of transport (Richer, 2008). However, it may also facilitate access to other kinds of public services.

Therefore an exchange poll has a triple functionality: urban, transport and services (Richer, 2008). The relation between these three functions is depicted in figure 2.

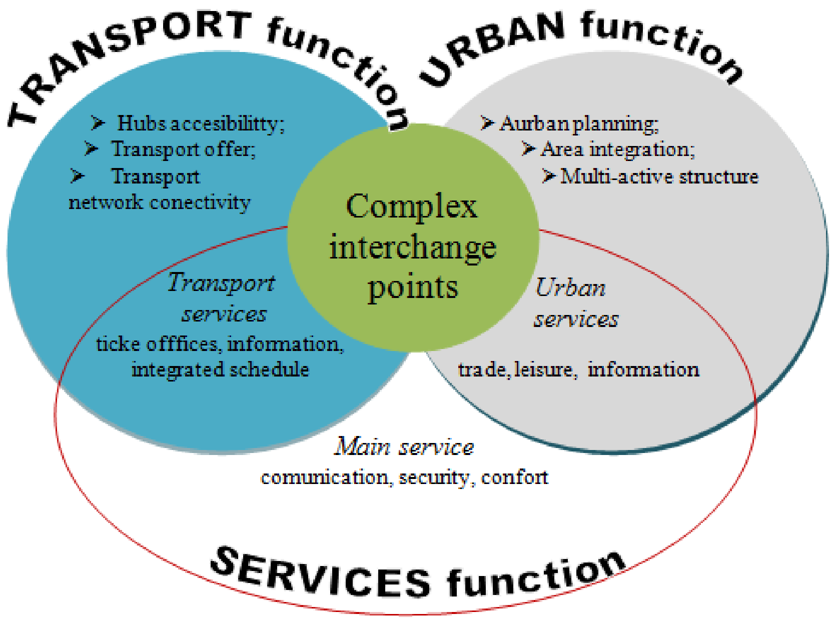

FIGURE 2 - THE THREE FUNCTION OF AN INTERCHANGE POINT (AFTER RICHER, 2008)

The services function of the passenger in interchange points plays a significant role in increasing the attractiveness of the public transport system by offering a range of facilities or methods to ease up the access to this kind of service. A variety of possibilities to attract passenger could be used: integrated parking fees, synchronized schedule for every transport mean, built in spaces for leisure activities, specialised parking for bikes or other means and price discounts for those who use environmental friendly means of transport.

Theoretical and Empirical Researches in Urban Management
Volume 9 Issue 1 / February 2014

A sustainable transport system must satisfy the mobility needs of all inhabitants of a specific zone without compromising the environmental condition. Reaching this goal is a difficult activity mainly because the transport demand is generated by social groups which are heterogeneous in form, number or nature and most of the time they have divergent concerns. A good example is the urban street network which is shared among vehicles, trucks bikers and sometimes pedestrians (Popa and Movileanu, 2004).

3. CASE STUDY

The peri-urban transport around Bucharest has lack of integrated vision and coordination, two disadvantages with great negative impact at social level. A top list of this urban space's needs from the point of view of transport starts with a mass transport network spread throughout the municipal area and one completed by other individual transport means from bike, car or small shuttle busses.

The attention of the present case study is focused on the increasingly acute use of minibuses from Ilfov and other counties residents to reach downtown. An analysis of the bus stations dedicated for this sort of commuting in Bucharest shows that there are over 30 such locations which attract or generate more than 3,000 minibuses trips daily. Most of them being located in the centre of Bucharest in figure 3, they bring extra traffic congestion to Bucharest, rise the social costs and promote unjustified competition to the existing urban transport network.

This highly expensive competition results from the fact that most suburban commuters need at least one other transport mean to reach their urban destination. The following study will show that the relocation of these pseudo-interchange points to the outskirts of the municipal area will not restrain the mobility of the peri-urban commuters, but on contrary will finally increase their mobility in some areas.

The travel time is an indicator that shapes traveller decision to use a certain path or a particular mode of transport. The isochrones mapping provides the area which is covered by a service within a time limit using various public/private transport modes. An urban trip consists of different segments: the walking time towards the public transport's station (t_{1walk}), the waiting period for the vehicle to come (t_{1wait}), the time spent inside a transport vehicle ($t_{1travel}$), the time spent changing to another transport vehicle (t_{2wait}), the time spent inside the subsequent transport vehicle ($t_{2travel}$) and the walking time towards the final destination (t_{2walk}).

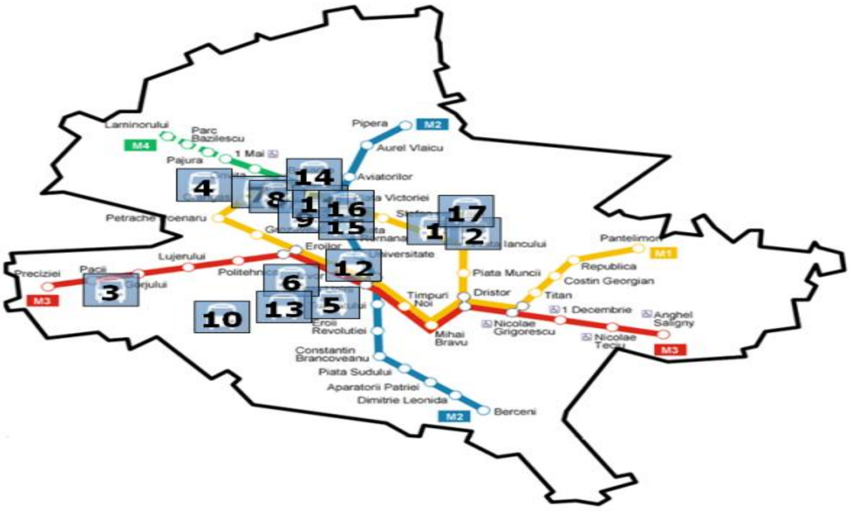

FIGURE 3 - PRESENT LOCATION OF THE PERI-URBAN TRANSPORT STATIONS

TABEL 1 - THE SCHEDULED NUMBER OF BUSSES ARRIVALS AND DEPARTURES (MAIN STATIONS - AUGUST 2012)

No.	Bus Station	Number of scheduled arrivals and departures
1	*Obor*	529
2	*C&I*	324
3	*Militari*	313
4	*Filaret*	261
5	*IDM Basarab*	211
6	*Gara de Nord-Baldovin*	148
7	*Rahova*	90

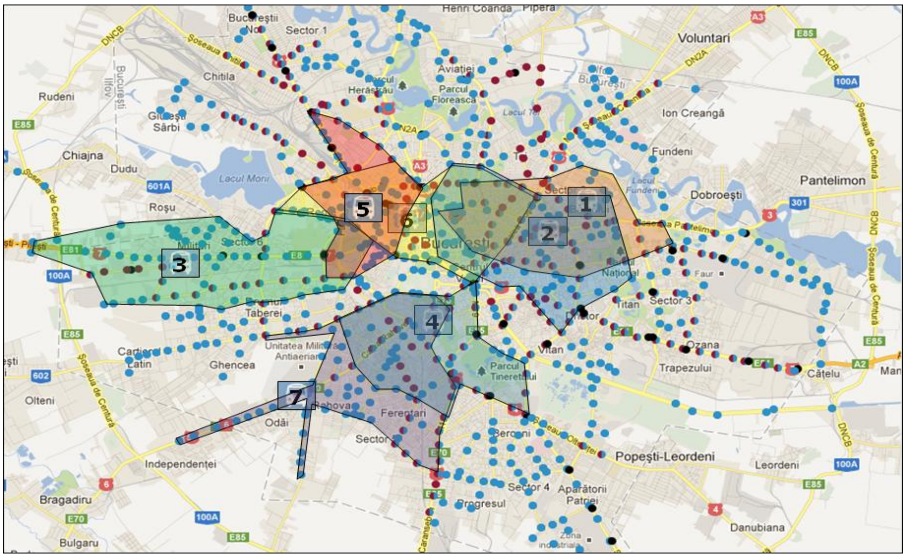

FIGURE 4 - URBAN TRANSPORT STATIONS WHICH ARE ACCESSIBLE IN 30 MIN.
– CURRENT SITUATION –

$$t_{urban} = t_{1walk} + t_{1wait} + t_{1travel} + t_{2wait} + \ldots + t_{iwait} + t_{itravel} + \ldots + t_{2walk} \quad (1)$$

where:

Theoretical and Empirical Researches in Urban Management
Volume 9 Issue 1 / February 2014

t_{1walk}; $t_{2walk} = d/v_{walking}$ – shows how well the transport system is integrated with other activities (d is the distance between the starting/destination point and the nearest transport station; vwalking is the walking speed aprox. 5 km/h);

$t_{iwait}=i_u/2$ – indicates the reliability of the *i* transport line (i_u is the time interval between two transport vehicles);

$t_{itravel}=D/v_{travel}$ – shows how well the *i* transport line is functioning (D is the distance travel with vehicle *i*; vtravel is the vehicle *i* commercial speed).

The objectives considered essential to express the efficiency of the transport network for the present case study is the number of stations that can be accessible in a certain interval. There were analyzed the urban transport stations which can be reached taking into account a duration of 30 minutes, including the minibuses travel time from the outskirts of Bucharest, the average transfer times and the journey time using other urban transport means. The urban public transport stations that can be accessible during an interval of 30 minutes for each terminal shaped the territorial coverage in figure 4.

The underground transport network of Bucharest solves partially the congestion and shortens the travel times in urban areas. Modal choice can be corrected by creating attractive modal change areas which provide exchange facilities and social benefits. This paper offers seven such proposals in order to achieve the multi-asset exchange centres. The new proposals are regarded as consistent because they are located near the major access routes to Bucharest; they are in accordance with the urban development plans and they offer a good connection to the mass transport mode. The proposed locations of the new transport hubs are:

- Pipera – link with A3 highway, underground connexion;
- Republica – link with national roads DN 2 ad DN 3, underground connexion;
- Policolor – link with A2 highway, underground connexion;
- Berceni – link with national roads DN 4, underground connexion;
- Rahova – link with national roads DN 6;
- Militari – link with A3 highway, underground connexion and Militari commercial centre;
- Straulesti – link with national roads DN 1A, underground connexion.

As previously considered, the urban transport stations which are accessible within 30 minutes from the new transport hubs where investigated and the area which can be reached within the interval mentioned is depicted in figure 5.

Due to the proximity of these centres to the underground stations, the number of stations that are accessible under the new circumstances is higher and because of their dissipated position the overlapping of each centre's access area is lower.

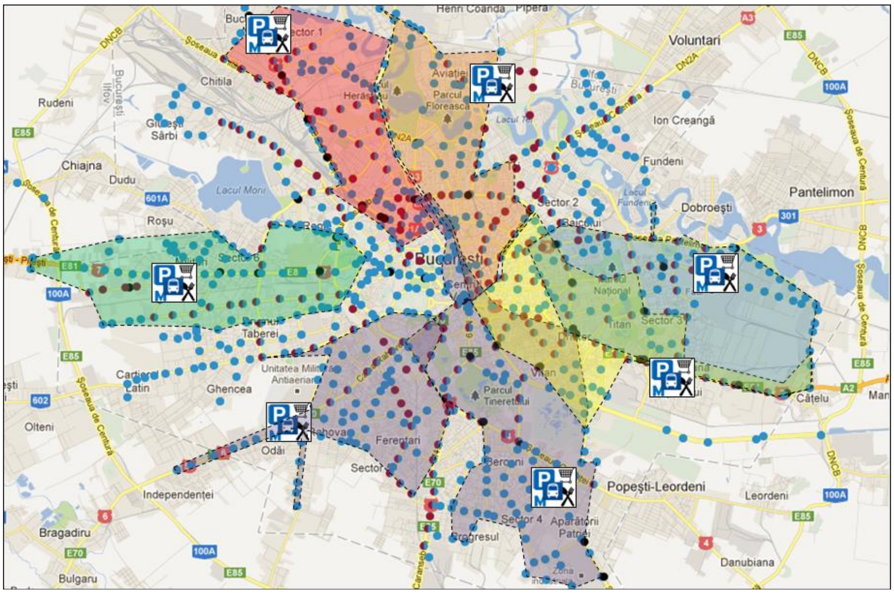

FIGURE 5 - LOCATION OF THE NEW TRANSPORT HUBS AND THE COVERED URBAN AREA –PROPOSED SITUATION–

The quantitative dimension of the effectiveness of the peri-urban public transport service to serve the urban areas can be expressed as the percentage of the total accessible stations using a predefined interval of time divided by the total number of stations, and the effectiveness of each intermodal station by the percentage of the station that can be reached from that specific location.

TABLE 2 - ACCESSIBLE STATIONS FROM EACH PERI-URBAN BUS TERMINAL –PRESENT SITUATION–

Bus terminal	Number of reachable stations	Percentage of reachable stations [%]
Autogara Obor	263	12,71
Autogara C&I	347	16,76
Autogara Militari	445	21,50
Autogara Filaret	329	15,89
Autogara IDM Basarab	173	8,36
Autogara Gara de Nord-Baldovin	396	19,13
Autogara Rahova	335	16,18
Total	2288	

Bucharest has a total of 2019 public transport stations served by the surface transport and 51 underground stations, which means a total of 2070 destinations points that have been considered for the determination of the effectiveness of the peri-urban transport. The results are shown in Table 2.

TABLE 3 - ACCESSIBLE STATIONS FROM EACH PERI-URBAN BUS TERMINAL
–PROPOSED SITUATION–

Exchange poll	Number of reachable stations	Percentage of reachable stations [%]
Pipera	386	18,65
Republica	330	15,94
Policolor	370	17,87
Berceni	420	20,29
Rahova	335	16,18
Militari	445	21,50
Straulesti	290	14,01
Total	2576	

The ratio of the total number of stations served by each bus station or multi-active pole that provides an indicator for the integration of the two components of the transportation network for the metropolitan area of Bucharest is set. The figures in tables 2-3 are showing that in the present situation a percentage of 57% represents the stations which are within a 30 minutes accessible time from the outskirts of the city using only the public transport, comparing with 72% which represents the percentage of the stations which will be reached under the new proposed configuration.

4. CONCLUSIONS

Over the time, the role of urban spaces has faced a constant change, transformation influenced by the constant rise of services level and their management. Besides the well-known transport means integration, this need of various public services integration to enhance the attractiveness of public transport has to be considered. The quantitative index for the assessment of sustainability for the proposed solution is the number of public transport's stations which can be accessible using new transport schemes that involves new multi-asset exchange centres. Such an approach increases access of outskirts residents to new urban areas and also offers a sustainable alternative to urban travel, facilitating the use of mass transportation.

REFERENCES

Alumur, S. & Kara, B.Y. (2008). Network hub location problems: the state of the art. *European Journal of Operational Researh,* 190 (1), 1-21.

Banister, D. (2005). *Barriers to Sustainable Transport. Institutions, regulation and sustainability*. New York, USA: Spon Press.

Button, K., Lall, S., Stough, R., & Trice, M. (1999). High-technology employment and hub airports. *Journal of Air Transport Management,* 5, 53-59.

Campbell, J.F. (1994). Integer programming formulations of discrete hub location problems. *European Journal of Operational Research,* 72, 387-405.

Campbell, J.F., Ernst, A., & Krishnamoorthy, M. (2002). Hub location problem. In Drezner, Z., Hammacher, H., (Ed.) *Facility Location: Aplication and Therory.* Berlin: Springer.

Contreras, I., Fernandez, E., & Martin, A. (2010). The tree of hubs location problems. *European Journal of Operational Research,* 202, 390-400.

Dennis, N, (1994). Airline hub operations in Europe. *Journal of Transport Geography,* 2, 219-233.

Grubler, A. (2004). Transitions in energy use. *Encyclopedia of Energy,* Elsevier Science, 6, 162-177.

European Community Comision (2007). Green Paper: Towards a new culture for urban mobility, COM(2007) 551 final, Bruxelles.

O'Kelly, M. (1998). A geographer's analysis of hub-and-spokes network. *Transport Geography 6.* 6, 171-186.

Popa, M. & Movileanu, R. (2004). Dezvoltarea infrastructurii dedicate deplasărilor nemotorizate. Proiect pilot pentru o zonă a municipiul Bucureşti, *Buletinul AGIR*, 3 ,116-120.

Raicu, S., Popa, M., Dragu, V., Costescu, D., & Rosca E. (2007). Optimisation Model Approach to Solving the „Just in Time" Periodic Transportation Problem. *A Way to E.R.A. Condeference Excellence Reasearch.* Brasov: Editura Tehinica.

Raicu, R. & Raicu, S. (2003). Transport demand, transport and traffic flow – key elements of city logistics. In *Logistics Systems for Sustainable Cities: Proceedings of the 3rd International Conference on City logistics*, Elsevier.

Raicu, S., Dragu, V., Burciu, S. & Stefanica, C. (2010). About the characterization of urban public transport networks and their teminals. *WIT press*, pg. 489-500,

Rebelo, J. (2012). Issues and Options in Large and Medium Size Metropolitan Regions of Developing Countries. Helsinki: *Helsinki Summer School in Transportation.*

Richer, C. (2008). L'émergence de la notion de „pôle d'échanges": entre interconnexion des réseaux et structuration des territoires. *Les Cahiers Scientifiques du Transport*, No. 54.

The Netherlands TRAIL Research School. (2006). Hub exchange operations in intermodal hub-and-spoke networks. Comparison of the performances of four types of rail-rail exchange facilities, Delft: *DELFT University of Technology*,.

UN World Commission on Environment and Development. (1987). *Our Common Future*, New York: WCED.

Yang, T.Y. (2009). Stochastic air freight hub location and flight routes planning. *Applied Mathematical Modelling*, 33, 4424-4430.