INNOVATIVE AND EFFICIENT TECHNOLOGIES FOR STRUCTURING THE "HUB-AND-SPOKE" NETWORKS OF INTERMODAL TRANSPORT, CONNECTED TO EUROPEAN STRATEGIES

Mihaela POPA[1], Şerban RAICU[2], Gheorghe DINU[3]

Rezumat. *Obiectivul general al proiectului este acela de a oferi un suport pentru implementarea Strategiei de transport intermodal în Romania 2020 şi pentru dezvoltarea transportului intermodal în acord cu cele mai multe dintre programele strategice europene. Proiectul include evaluarea consumurilor energetice specifice şi ale efectelor negative externe generate de modurile şi tehnologiile de transport terestre apoi stabilirea unei metodologii de amplasare/reamplasare a terminalelor intermodale de transport prin utilizarea modelelor matematice şi de simulare şi în final determinarea soluțiilor pentru asigurarea eficace, eficientă şi prietenoasă cu mediul a nevoilor de deplasare a bunurilor pe teritoriul național în concordanță cu strategiile la nivel european – structurarea ierarhică a rețelelor intermodale „hub-and-spoke".*

Abstract. *The general objective of the project is to offer a scientific support for implementing the Strategy for intermodal transportation in Romania 2020 and for the intermodal transport development according to most of the European strategic programmes. The project includes the evaluation of the specific energy consumption and of the negative externalities generated by terrestrial transport modes and technologies then establishing a methodology for the location/relocation of intermodal transfer terminals, by using mathematical and simulation models and finally determining solutions to assure efficient, effective and environmentally friendly freight transport demand — hierarchical structuring of hub-and-spoke intermodal transfer networks.*

Keywords: transport, intermodal, "hub-and-spoke", networks.

1. Introduction

Among the specific objectives of the project is the evaluation, in a comparative study of the specific energy consumption (in relation to the activity measurement specific unit) and of the negative externalities generated by terrestrial transport modes/technologies for identifying, firstly, the technical-economical limits/zone of the performance for each mode/technology in a given situation and, secondly, to determine (for type of goods, volumes, relations, etc.) the possibilities and

[1]Prof., PhD, Eng., Transport Faculty, Politehnica University of Bucharest, Bucharest, Romania, (mihaela.popa@upb.ro).
[2]Prof., PhD, Eng., Transport Faculty, Politehnica University of Bucharest, Bucharest, Romania, (s_raicu@rectorat.pub.ro).
[3]Senior researcher, Transport Research Institute INCERTRANS, Bucharest, Romania, (gheorghe.dinu@incertrans.ro).

conditions for intermodal cooperation and/or necessities/conditions for modal competition.

Through generalized total costs, containing: monetary costs of the transport, social cost elements for operators/carriers (delay and insecurity due to congestion) and external cost elements (non-renewable resource consumption, infrastructure maintenance costs, effects on the environment: pollution, noise, vibration, etc.) will identify the technical-economic performance limits/zones for each mode/technology of transport.

The research results are: a methodology of selection for the energy consumption and for the negative externalities assessment, a methodology to locate the intermodal terminal using mathematical and simulation modeling, solution for an efficient, effective and environmentally friendly freight transport.

2. Project topic and its practical relevance

The activities of the project result from two important strategic and fundamental papers in transportation area: on EU level – White Paper. Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system and on the national level: Romanian intermodal transportation strategy, 2020.

While road transport has a dominant role and its consequences are growing (congestion, pollution, insecurity, number of accidents), developing intermodal transportation is considered at all levels as a solution for rebalancing the transport market. Transferring road trips of long distances towards railway and, if possible, to inner water ways needs important investments to build an exploit the terminals.

Problems brought by replacing long distances road transportation with intermodal transportation need studies and researches that mainly aim: developing an intermodal transportation system that would ensure quality transport services whether the tariff (price) for transportation is similar to the one of road transportation.

Planning intermodal transport services that would allow road transportation transfer to the railway system needs exploiting not just one terminal or some of local or regional interest but a whole intermodal transfer terminal network, with certified utility both on national and European level. As transfer and, sometimes, processing transport flows within the terminals lead to increased costs, the functions and efficiency of these terminals are essential to intermodal transportation development.

Railway-road intermodal transportation uses: collection/distribution road network for short distances, then railway network for long distances and as a final element

(see Figure 1), special infrastructures within intermodal terminals to realize the trans-shipments between two transport modes. The competitiveness of this transport depends on the terminal location within the territory and also on transfer costs. In Figure 1, centers like a1, a2, …, b1, b2, …, c1, c2, … might be the origins/destinations of freight or, in an intermodal network hierarchically structured, in some conditions, hubs of a lower level to terminals A, B, C.

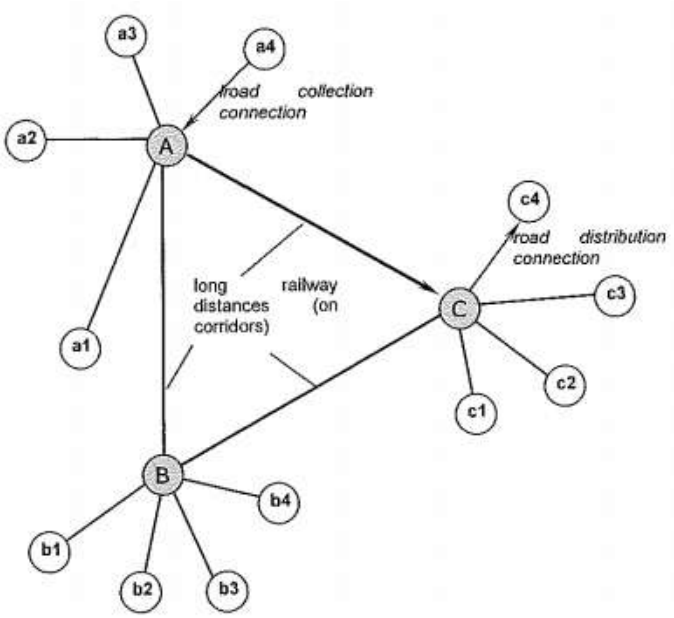

Fig. 1. Simplified example of railway-road transportation network, intermodal integrated by intermodal transfer terminals A, B, C

In this framework, the main foreseen projects results are:

- Evaluation of specific energy consumption of the generated externalities considering multiple variables of transport achievement, in different single-mode way (road, railway, or inland water ways) with the goal of determining limits and competition and/or cooperation zones between terrestrial transport modes;
- Mathematical and simulation models and methodology for location/relocations of the intermodal transfer terminals on the intermodal transport integrated network;
- Study for freight transport demand consolidation in transport and traffic flows for supply/distribution and solutions to design the hub-and-spoke structure networks on different levels within Bucharest's metropolitan area;

- Intermodal transport and transfer technologies harmonization in network hubs by developing and using the concept of Terminal Transfer Performance Indicators;
- Pilot model for simulating the activity of a terminal from hub-and-spoke network in different scenarios of facility development within the terminal, using integrated informatics systems;
- Location/allocation strategy for hubs and intermodal transfer terminals supported by mathematical and simulation modelling;
- Persuasive and incentive measures and associated guide-lines in order to implement the proposed solutions and to bring legal regulation for intermodal transport development.

We appreciate that the supposed results answering the needs of implementing fundamental strategic directives in the field of research have expected practical relevance.

3. Project contribution

Intermodal transport particularity is that the goods are transported from an origin to a destination using successively different transport modes without changing the load unit. The load units used in intermodal transport are containers, swap bodies and semi-trailers. Intermodal transport process supposes going through the stages presented in Figure 2. To provide quality intermodal transport services it is necessary to optimize all process sequences and the interactions between transport modes in the terminal to be realized without any difficulties.

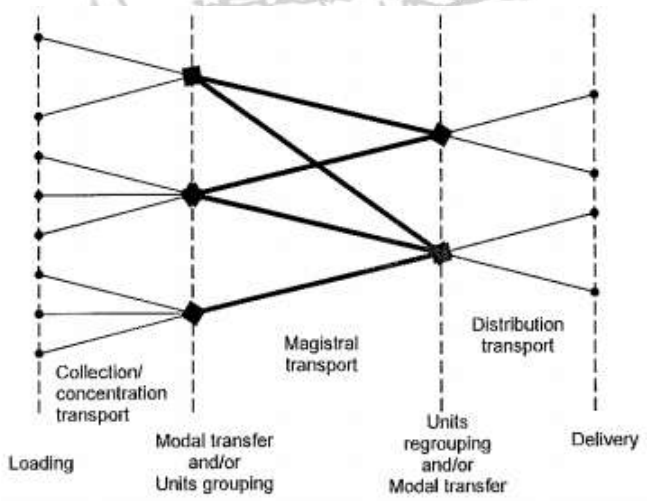

Fig. 2. Stages of the intermodal transport (Costescu, 2010)

The analysis of the condition of competition between transport modes and of the opportunity for promoting and developing the intermodal transport, assumes, as a first step, the study of existing requirements on the transport market. A suggestive analysis of the modal distribution of goods, on significant categories, may be the one in which it is considered a land transportation mode represented on a separate side of a triangle – road, rail, inland waterway, as in Figure 3. Among the participants in the transport process, those who decide ultimately the transport mode are the shippers and then the shipping houses. For certain segments of the transport chain, the logistic companies and intermodal transport operators can also contribute to modal choice. In most cases, shippers choose the mode of transport according to subjective criteria (tradition, experience, recommendations) without analyzing enough the existing alternatives – fact caused by the lack of transparency in the transport market. In the cases in which the shippers transfer the decision of modal choice to the shipping houses, those being also the road transport operators or closely related to a rail company, they decide mostly according to financial interests.

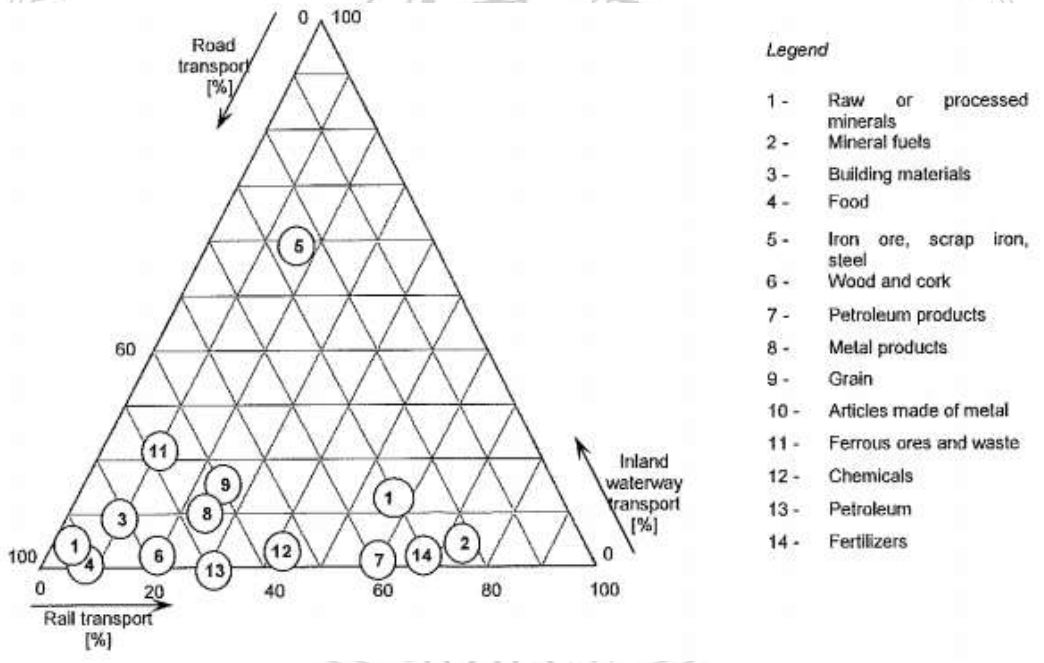

Fig. 3. Modal split by category of goods for transport carried out in Romania in 2004 (Costescu, 2010)

In order to compare the transport modes and to determine the best alternative we must consider not only the transport price, but also the total transfer costs (storage costs, administrative costs, insurance, taxes, loss of value of the goods during transport, buffer inventory costs, mainly due to changes in demand and transport

regularity, etc.). The service quality indicators, evaluated based on the reliability, flexibility, frequency and difficulty to be quantified in monetary values, must also be taken into account.

At local level, freight transport in cities contributes with 15-20% to the total traffic without considering the goods transported by the vehicles of the buyers. To improve the existing situation in delivery/returning the goods in crowded areas there are known two types of possible action: (i) - actions on the urban network management, for example on the traffic routes, on the places of stopping, on the delivery areas, on the parking conditions and on the type of the allowed vehicle; (ii) – creating appropriate equipment for the urban logistic areas (see Figure 4) designed for optimizing the distribution of goods in cities based on a functional and environmental plan that consider the points in which take places the load rupture. This interface can be developed either by the public sector or the private one or in partnership and assuming the responsibility leads to the success or to the failure of the implementation of technological innovations. Making logistic platforms of urban logistic places is conditioned by identifying the intermodal terminals and by assigning (distributing) the significant volumes of logistic activities, reserving or creating adequate spaces in urban areas, fiscal policies incentives for the development of public-private partnership, stimulating regulations for all involved parties.

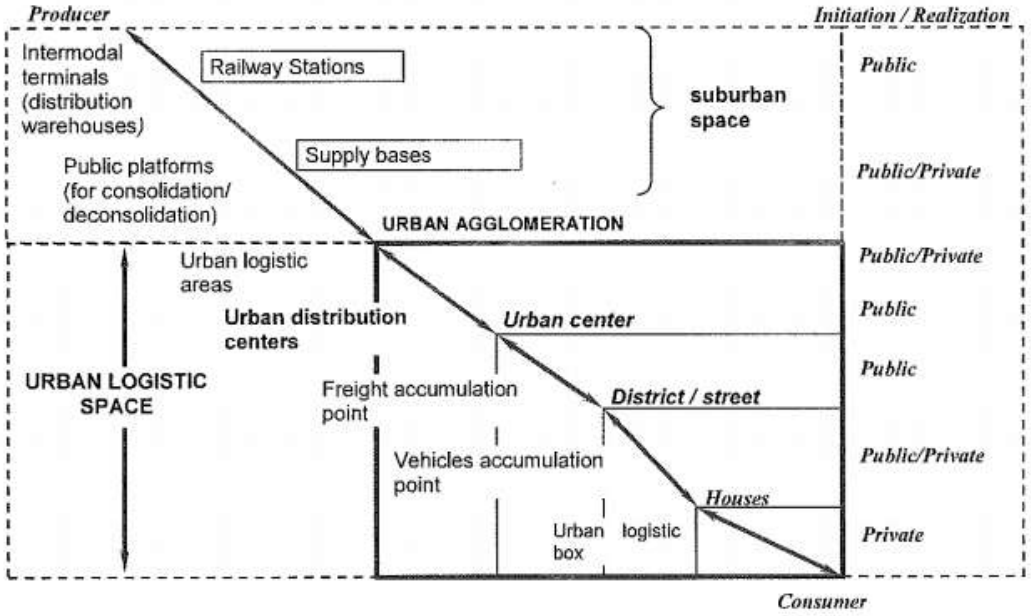

Fig. 4. The connection between the intermodal terminal and the logistic platforms serving urban space, in relation to the public/private responsibility for technological development/innovation (Boudouin, 2006).

Given the heterogeneity of the urban space and the difficulty to measure the variables that occur in the models of location, we can formulate critical observations on the solution described in the literature, mostly related to the fact that flows allocation is made on the considered network without capacity restriction, which represents an oversimplification in the case of metropolis like Bucharest.

In the present research we propose the development of a case study for consolidating the transport demands, in transport flows and then in traffic flows for supply and distributing activities for Bucharest's metropolitan area and to identify the solution to configure the network hub-and-spoke, on different hierarchical levels, taking into account the peculiarities of the transport network in the metropolitan area and special and temporal characteristics of the demand of goods (time value for freight transport, associated external costs, transport modes, energetic efficiency, etc.).

In relation to the above, in terms of deepening the sustainable development requirements, further researches on the location, size, assignation of users and transport routing and hence the hierarchical structure of hub-and-spoke network for intermodal transfer in conditions of cooperation of transport modes on a unique market, which became planetary, are necessary and appropriate.

4. Project outcomes

The expected research results of the project are:

1. Identification of the most adequate methodology for the energy consumption and the negative externalities, during a comparative study of the already developed models/methods and elaboration of "Modal and Intermodal Indicative Register of Freight", on CEFTA categories, considering all technical, commercial and logistic characteristic brought by using each transport mode and/or each intermodal combination;

2. Establishing a methodology of location/relocation intermodal transfer terminals, by using mathematical and simulation models. The result of the research activities for this is represented by solutions of locating intermodal transfer terminals on the integrated terrestrial transportation network, in different simulation scenarios;

3. Determining solutions for assuring efficient, effective and environmentally friendly freight transport demand – hierarchical structuring of hub-and-spoke intermodal transfer networks. The results of the activities aiming this goal are:

(i) Case study (adopting a "down-to-up" approach) to identify and consolidate transport demand in freight flows, then in transport flows and finally in traffic flows, in the case of supply/distribution within Bucharest's metropolitan area;

(ii) Solutions to configure hub-and-spoke networks on more levels for supply/distribution in Bucharest.

(iii) Solutions to harmonize intermodal transfer and transport technologies in network's hubs, by investigating the most performing terminals (private or public) in Romania and Europe.

(iv) Pilot model for simulating an intermodal transfer terminal functioning of a hub-and-spoke network for different stages of facilities/equipment/information systems/infrastructure configurations development within terminal.

(v) Hubs and intermodal transfer terminal location/allocation strategy based on mathematical and simulation models.

(vi) Persuasive and incentive tools guide in order to implement the proposed solution and bring legal regulations for intermodal transport development.

Conclusions

In conclusion, the aggregate objective of the research activity is represented by an intermodal transfer terminal location strategy within the terrestrial transport network, based on flows allocation in relation to the lowest external costs and energy consumption and by using mathematical and simulation models in different stages of facility development within hubs and transfer terminals of the integrated transport hub-and-spoke network. Some original features that deserve to be highlighted, also proving the innovative character of the proposal, are the following: in the studies from freight transport area, the freight transport demands are expressed in unit of mass. In the proposed research, to analyze and to evaluate the alternatives of organized transport services and to identify the flows that can be transferred from road transport system to the multimodal one, the transformation of ex-ante demand from mass units in load units is necessary. The transformation procedures will be applied on categories of goods (CEFTA) and the categories of load units (see Figure 6). Expressing the transport flows in load units is an important stage, of whose accuracy depend the estimation of intermodal system components request and implicitly the costs. If we consider the simple example of the distribution of a certain quantity of goods in two units instead of one larger capacity, then of course, we will find that the assignment will double the number of operation in the terminal and it will increase the transfer cost (energy resources, environmental effects, transfer times, etc.). In the proposed research we will use a virtual network, which includes not only the formalization of transport networks, but also the formalization of the transfer operation realized in terminals. Geographic information systems provide appropriate tools for modelling transport networks. We will include in this network the rail network, the road network in Romania's national territory, intermodal transfer terminals where we will formal represent the intermodal transfer, in relation with the

various facilities/infrastructures/configurations. The proposed simulation model for the intermodal transport network will allow the evaluation of locating the terminals by integrating the flow allocation procedures, the identification of flows with common routes, the procedures of concentrating the flows for the scheme proposed for the train formation.

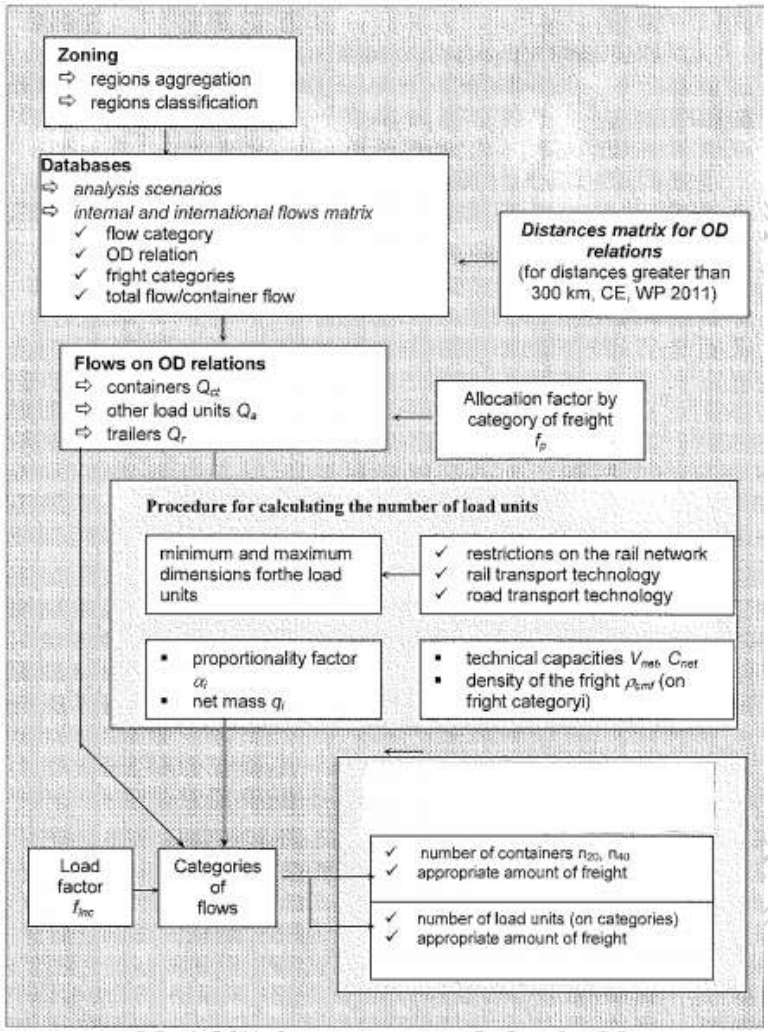

Fig. 5. The logical scheme of the transformation process of the transport demand in freight and transport flows

The proposed research develops mathematical and simulation models which take into account elements of quantitative nature, measurable/quantifiable, such as: energy consumption, the external effects of transport for different modal alternatives and intermodal combinations in relations to the characteristics of the goods' movement applications, limits and performance areas of transport modes

and technologies related to the nature of the goods and the technical, commercial, logistics characteristics, structuring hub-and-spoke land transport networks on different hierarchical levels, in relation to the scale of service, harmonizing transport and transfer technologies in intermodal terminals and using some performance indicators of intermodal transfer in terminals.

R E F E R E N C E S

[1] Y.M. Botekoning, *Hub Exchange Operations in Intermodal Hub-and-Spoke Operations: A Performance Comparison of Four Types of Rail-Rail Exchange Facilities* (University of Technology, Delft, Netherlands, 2006).

[2] D. Boudouin, *Guide méthodologique. Les espaces logistique urbains. La documentation française* (Paris, France, 2006).

[3] J.F. Campbell, *Integer Programming Formulation of Discrete Hub Location Problems*, (European Journal of Operational Research, 1994) Vol. 72 (2), pp. 387-405.

[4] D. Costescu, *Soluții eficiente pentru organizarea spațiului logistic urban* (Buletinul AGIR "Transporturile şi amenajarea teritoriului", 2009) Nr. 4, pp. 159-162.

[5] D. Costescu, *Researches on Multimodal Transport Network for Medium Distances. Mathematical Models and Simulation for Terminals' Location* (PhD thesis, Politehnica University of Bucharest, 2010).

[6] European Commission, *The White Paper of Transport. Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System* (Brussels, 2011).

[7] M. Huschebeck, J. Allen, *Best Urban Freight Solutions II* (European Commission, Brussels, 2005) Deliverable D1.1.

[8] M. Labbe, *Facility Location: Models, Methods and Applications*, in M. Labbe, G. Laporte, K. Tanczos, K. Toint, P.(ED.), *Operations and Decision Aid Methodologies in Traffic and Transportation Management* (Proceedings of NATO ASI, Balantonfured, Hungary, March 10-21, 1997, Series F: Computer and System Sciences, Vol. 166, Springer, Berlin, 1998) pp. 264-285.

[9] M. Popa, *Economia Transporturilor* (Politehnica Press, Bucharest, Romania, 2009).

[10] S. Raicu, E. Rosca, *Asupra distribuției containerelor între terminalele de transport şi beneficiari* în "*Concepte intermodale în transporturi – Lucrările seminarului proiectului IM7Danube*" (Editura Agir, Bucharest, Romania, 2006).

[11] E. Taniguchi, R.G. Thompson, T. Yamada, D.V. Ruin, *City Logistics: Network Modeling and Intelligent Transport System* (Elsevier Science LTD. Oxford, UK, 2001).