INTERMODALITY IN URBAN PASSENGER TRANSPORT

Flavius GRIGORE[1], Petruț CLADOVEANU[2]

Rezumat.

Intermodalitatea este o parte integrantă a mobilității durabile, iar îmbunătățirea acesteia este deosebit de importantă în zonele urbane aglomerate. Orașele sunt în creștere în prezent, la fel și cererea cetățenilor pentru mobilitate. Pe scară globală, traficul individual este motorizat,abia capabil să răspundă acestei nevoi din cauza costurilor de proprietate și datorită lipsei unei infrastructuri corespunzătoare. În afara de asta, traficul cu automobilul personal este responsabil pentru majoritatea sarcinilor de circulație actuale, cum ar fi poluarea aerului, blocajele de trafic, zgomotul și accidentele. O astfel de utilizare a diferitelor moduri de transport într-o singură călătorie se numește "intermodalitate" și este un subiect de lucru încurajat într-un context național, european și mondial.

Abstract.

Intermodality is an integral part of the sustainable mobility and its enhancement is of vital importance particularly, in high congested urban areas. Cities are growing nowadays and so is their citizens' demand for mobility. On a global scale, motorized individual traffic is hardly capable of meeting this need due to its ownership costs and due to the lack of an accordingly large infrastructure. Besides, motorized individual traffic is responsible for the majority of today's traffic burdens, such as air pollution, traffic jams, noise, and accidents. Such a use of different transport modes within a single journey is called "intermodality" and is a work topic fostered in a national, European, and world-wide context.

Keywords : intermodality, urban transport, passenger intermodal transport, public transport

1. Introduction

An integral part of sustainable mobility is intermodality, and in busy urban areas an improvement is very important.

Intermodality refers to improving the efficiency and attractiveness of a single journey made with multiple modes of transport (eg walking, train and bus) in order to provide passengers with a smooth journey. This requires the creation of integrated transport systems by harmonizing the various transport services and by

[1]Eng., Research and Innovation Development department, SC INCERTRANS SA, Calea Griviței 391-393, ZipCode 010719, Bucharest, Romania (flavius.grigore@incertrans.ro)
[2]Eng., Research and Innovation Development department, SC INCERTRANS SA, Calea Griviței 391-393, ZipCode 010719, Bucharest,Romania (petrut.cladoveanu@incertrans.ro).

creating connections between different modes of transport, for example in the park and on the road. Five key measures that can improve intermodality are: 1) Conveniently located transport stations and interconnection points offering a wide range of options for further journeys (eg public transport services, bicycle sharing, walking routes safe, etc.); 2) a comprehensive public transport, cycling and walking network; 3) intermodal journey planning software; 4) integrated tickets and e-ticketing; 5) and price and demand management schemes. [3]

Changing modes of transport should be as easy and easy as possible for all users. The background is that 73.4% of passenger transport in Europe is made by road. This dominance of road transport brings a high flow of vehicles, environmental issues, noise pollution, reduced public safety, and the limitation of the effective effects of urban transport. Implementing an efficient and competitive transport system is a first step towards the Single European Transport Area and increasing transport competitiveness in Europe. Intermodality is defined by integrating at least two modes of transport in one journey, with easy and easy transfer, without losing time and money, using the same way of payment and the same way of planning the trip. [9]

European cities have problems with the large number of cars due to the expansion of the population and the economy, threatening accessibility, quality and the natural environment. In order to withstand the motorized personal motor competition, which offers comfort in making home travel at work, intermodal transport, representing the effective integration of different modes of transport and travel services, becomes a necessity for the use of public transport and non-motorized transport.

These developing cities face a sharp increase in road traffic congestion, a high increase in CO_2 emissions and a demand for parking space. This, therefore, makes us realize that the use of personal cars is becoming less attractive in cities. An alternative to personal cars becomes the bicycle rental and car-sharing systems that are underway, public transport operators provide more and more integrated services and the use of new technologies is on the rise, smartphone usage simplifies access to traffic information and the purchase of tickets.

The very high potential of intermodal transport in contributing to clean, smart and sustainable transport, transferring passenger mobility from the road to public transport. Some of the main aspects of urban transport are the development of integrated urban solutions, the connection of infrastructure with transport services, the interaction between users and multimodal services. Challenges are multiple, in many European cities there are many carriers, these operators do not offer a unique tolling system, the links between transport play an important role, the risk of loosing the links can exist, if one of the means used is late or canceled.

Intermodal passenger transport is defined by connecting fast and high-capacity modes of transport, such as interurban or subway trains, to local transport modes such as trams, buses or bicycles. Linking these modes of transport during the journey will help travelers quickly change modes of transport and keep them away from the temptation to use the personal car motivating the poor correlation of modes of transport and the great distances between them. [9]

For urban intermodality, the links between public transport and public transport, generally known as Park & Ride, represent the optimal transition to public transport networks. The link between public transport and interurban networks is a basic point of intermodality, thus helping travelers to use public transport to commute without increasing travel times or requiring long walks. Encouraging the use of bicycles from the dwelling to public transport points through the implementation of bicycle tracks and car parks also helps an efficient intermodality. In some cases, allowing bicycles to be transported by means of public transport contributes to optimal intermodality. [9]

Interconnecting modes of transport requires infrastructure and vehicles that are compatible for this type of service to eliminate the lack of compatibility between different modes of transport, vehicles, terminals, tolls and transfers. Harmonization of different transport modes and services is done through intelligent, digitized services that enable them to connect permanently to users in order to provide real-time information, thus helping travelers plan their travels efficiently in all respects. [9]

2. Intermodal journeys in major cities

The effect of intermodal transport is how to move from the use of personal cars to the adoption of public transport and non-motorized vehicles. Thus, a good connection between modes such as bicycle, tram, metro and walking is what is understood by intermodal transport.

The objective is to reduce the cost per traveler transfer. Urban transport plurality and the rehabilitation of private capacity, passengers not only use the most cost-effective way of travel into account in terms of monetary budget, but also look for the most cost-effective way and comfort.

As Regarding the use of alternative vehicles, they have regained their status as a means of public transport, but the use of bicycles is still poorly used compared to other urban transport modes. Figure 1 shows the advantages and disadvantages of public transport (PT) and individual vehicles (IV), so as to eliminate the different characteristics of the development of urban public transport.

In general, external causes resulting from the use of motorized vehicles are air pollution, greenhouse effect, noise, energy consumption, safety and congestion that are more and more difficult to bear and are far more serious than the adverse effects of public transport.

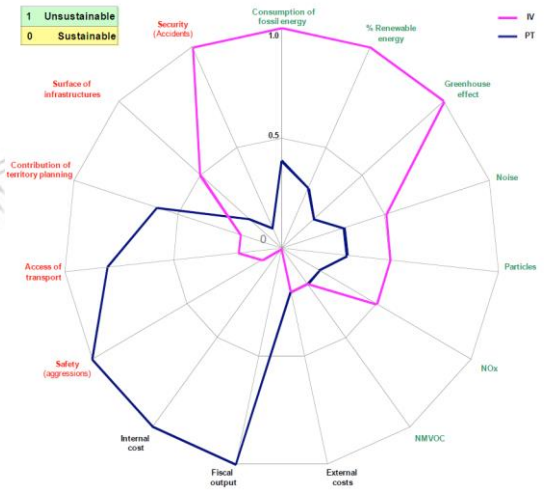


Fig. 1. Comparison between individual vehicle and public transport

In order to reduce the external effects caused by the use of personal cars and to increase the quality of life, we must limit as much as possible the use of personal vehicles for journeys in the city. Table 1 shows the indicators for each mode of transport

Table 1. Displays of transport modalities

Transport mode	Max. Speed	CO_2	Personal energy consumption	Price
Walking	5 km /h	0 g/km	280 kcal/h	€ 0/km
Cycling	12 km /h	0 g/km	300 kcal/h	€0/km
Motorized individual traffic	Loaded from SUMO	150 g/km	85 kcal/h	€0,45/km
Public transport	As scheduled	75 g/km	170 kcal/h	€0,95/trip

The use of intermodality for daily journeys is more supported now, as it brings profit and integrates the advantages and disadvantages of modes of transport. The concept of intermodal transport can reduce the use of cars in crowded urban areas.

At the moment, travelers' intermodal journeys, combining two modes of travel on the same journey; for example, public transport + personal car; public transport, etc. is the main passenger journey in urban areas or peripheral urban areas.

In figure 2 we explain a way of transportation in the city. We think the passenger leaves nearby homes in the city center at his place of work. This shift can have 17 parts. The traveler will first use it (bicycle) to get to the regional train station where he is going to a train passing through the central area of the city, and then the person uses another mode of transport to arrive at the nearest station to his office Eventually, the person walks from the last station to the office.

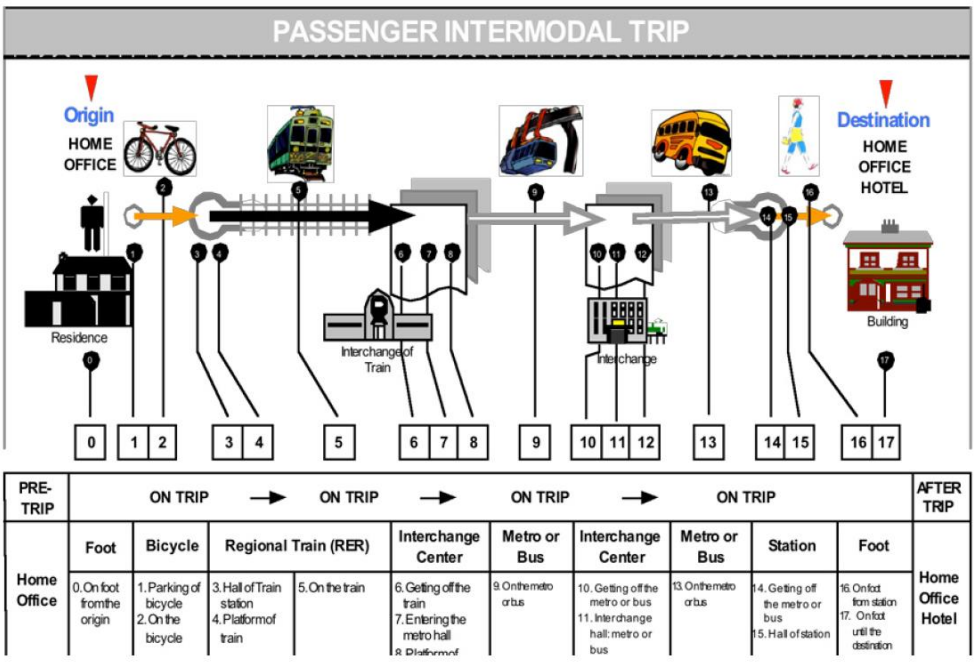


Fig. 2. Schedule of the passenger intermodal journey

Although intermodality in public transport is not recent, it presents issues of integration and consistency between public transport and personal car transport. In order promoting intermodal journeys, they must be well organized so that passengers consider it an advantageous alternative to the passenger car.

2.1. Case study -Paris and Shanghai

For example, in Paris, the combination of cars and urban transport on the same trip has a percentage of 1.2% of the total journey, this situation has not changed for thirty years. Try it to explore the potential demand for intermodality in two cities with very high capacities (Paris and Shanghai) regarding the conditions of intermodality.

Examination of modal fragmentation shows that the car is at the forefront of public transport in the busiest region of Paris (43.9%), and the bicycle always occupies the first position compared to other alternative routes in Shanghai (25.2%). According to the Table 2, if we look only at motorized journeys, we find

that motorized journeys have a high percentage of 70% in the large Paris region and 48% in the city of Shanghai. The second ranking of travels the largest region in Paris is walking (34% of the total trip); on the contrary, in the city of Shanghai, walking is more common than cycling. [5]

The intermodality of these two cities, conventional vehicles, plays a very important role every day, although the rate of use of internal combustion vehicles in Shanghai reaches only 22% in 2004 (compared with 10.9% in the 1995 total journey). The potential for crossing between motorized and non-motorized modes has taken place in Shanghai since then in the last 20 years. [5]

In the comparative analysis, the vast majority of trips is the only way: 96% of the total trip to Paris and 89.8% of the total trip to Shanghai (Liu, 2006) in a single way on the same voyage. The use of intermodal services journeys is very small and their evolution can not be presented as a significant increase.

In Paris the advancing the intermodal journey reveals that the most used way of intermodal travel is the subway combined with the bus (about 3% of the total number of trips) and the bi-modal or tri-modal share between public transport / car remains very weak , 5% of the total trip).[5]

Concerning Shanghai, the most common combined use of intermodality travel is metro and bus (with 4.9% of the total journey and the share of the bimodal between internal combustion vehicles / urban transport 3.1% of the total voyage.

Table 2. Distribution mode in Paris and Shanghai (%)

Mod	Total displacements		Motorized trips	
	IDF*	Shanghai**	IDF	Shanghai
Car	43.9	11.3	66.7	24.7
Motocycle	2.5	10.6	3.8	23.2
Total	46.4	21.9	70.4	48.0
Metro	12.5	2.5	19.0	5.5
Bus	7.0	16.0	10.6	35.1
Taxi	---	5.2	---	11.4
Total	19.5	23.7	29.6	52.0
Bicycle	---	25.2	---	---
Walking	34.1	29.2	---	---
Total	100.0	100.0	100.0	100.0

The increase in intermodal travel in the larger Paris region increases by 8% between 1976-1991 (6.65% in 1976 and 7.19% in 1991) and, at the same time, the increase in the number of car journeys has increased from 24 % 1976-1991 (35.7% in 1976 and 44.4% in 1991). In other words, the rate of use of non-

motorized modes decreased by 21% between 1976-1991 and the rate of use of public transport remained stable over the past 15 years.[5]

In the Table 3, we find information on intermodal travel between cars and public transport in a fairly low percentage. On the contrary, the increase in the use of intermodal journeys between cars and train reached 55.6% due to the very dense rail network. The key to intermodality is not only to provide a good choice for passenger transport but also to transfer from the use of personal vehicles to the use of public transport.

Table 3. Evolution of intermodal travel in Paris

Modes	1976	1991	Growth(%)
Metro,Bus	3.00	3.64	21.3
Car and public transport	1.41	1.50	6.4
Car,Metro	0.86	0.71	-5.8
Car,Bus	0.10	0.09	-0.1
Car,Train	0.45	0.70	55.6
Others	2.24	2.05	

2.2. Bucharest case study

In order to make the transfer from the private car to the public transport, the transfer from one mode of transport to another, it is necessary to organize the intermodality in the big and medium cities where it is totally lacking or is not developed, as is the case of Bucharest. It benefits from an extensive infrastructure network for multi-modal public transport but one that has suffered over the years due to a lack of funding for maintenance or investment and is affected by the rigid separation of modes at certain levels.

Table. 4. Services provided by public transportation modes

	Metro	Tram	Bus	Trolleybus
Number of lines	4	25	80	15
Vehicle capacity (seats)	1,200	200	50	50
Average daily departures	452	3,447	10,813	3,255
Average daily service capacity (%)	27%	35	27	8
The length of the route (km)	146	479	1,627	259
Daily vehicle mileage	9,948	33,527	103,340	22,897
Daily vehicle hourly average	1,885	2,547	8,054	2,068
Start of operation in the morning	5:00	5:00	5:00	5:00
Finishing the evening operation	23:00	23:00	23:00	23:00
Average rate lei (one trip)	2	1.3	1.3	1.3
Average number of passengers, daily	624,191	489,706	885,428	198,028

Within Bucharest there are extensive metro, tram and trolleybus networks. Buses provide 80% of the service mileage but only 27% of the service capacity (see Table 4). Electric propulsion is used for 70% of passenger capacity and is likely to be a factor contributing to reduced CO2 levels in the city.

Bucharest City has a good metro network with state-of-the-art technology and rolling stock providing robust, reliable and fast service. The currently operated network comprises 4 lines with a total area of 69.25 km of double track and 45 stations. Current passenger numbers are between 600,000 and 800,000 passengers per day.

Pedestrian infrastructure is not satisfactory across the territory studied. In Bucharest, a high proportion of pedestrian infrastructure is unsatisfactory from a functional and environmental point of view, it is under-dimensioned and / or abusively occupied by cars parked irregularly or with various obstacles in much of the city (Fig. 3).

The ambience of pedestrian traffic is generally affected by the aggressive presence of vehicles in urban spaces and landscapes, pollution, noise, insecurity generated by motorized traffic. Despite poor conditions, there are a large number of pedestrian trips, especially for shopping (32% of total trips) and to accompany children (37%).

Fig. 3. Infrastructure for pedestrians occupied by vehicles parked illegally (left) and inaccessible to persons with reduced mobility (right)

The use of the bicycle for transport is very low in Bucharest. At present, Bucharest has about 10 km of cycle tracks and those in a deplorable or non-functional condition, except for the Calea Victoriei runway. [8]

By way of comparison, Figure 4 shows the modal distribution in Copenhagen and Amsterdam, cities with a congestion index of 19% and 21%, respectively. These cities have managed to reduce both car and public transport by encouraging cycling, and an option that can be particularly attractive to Bucharest because bicycle tracks are a cheap and easy to install infrastructure. There is a

small number of bicycle infrastructure in Bucharest. In the past, bicycle tracks have been marked on the sidewalks, but this practice has ceased. By comparison, Copenhagen has 416 km of cycle tracks and about 500,000 bicycles. Amsterdam has more than 500 km of bike tracks. A questionnaire was distributed among the inhabitants of Bucharest asking for their preferences for the extension of the network. Figure 5 shows the map of your preferred cycling infrastructure, ranked according to the number of respondents indicating the segment as a preference.

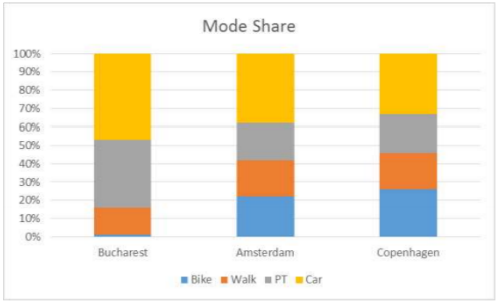


Fig. 4. The modal distribution for the selected cities

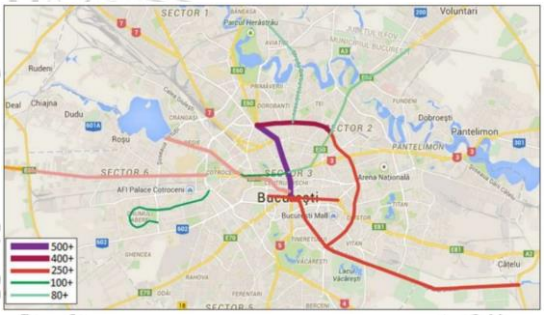


Fig. 5. Bicycle Infrastructure Preferences for Bicycles

The physical forms of intermodality vary from simple systems, for example, to the interconnection of different transport stations in an organized proximity (Fig. 6), to complex systems, multimodal polymodal intermodal poles (Fig.7). [4]

Fig. 6. Simple form of intermodality - transport stations - subway and tram - Obor, Bucharest North, Bucharest

Fig. 7. Intermodal complex comprising Montparnasse train station, Paris

The city of Bucharest and, moreover, its territory of influence are lacking a coherent system of intermodal nodes, this leads to the use of the personal car. Simple forms of intermodality are needed to integrate park & ride and / or bike & ride parking and public transport stations (Fig. 8), allowing and encouraging the use of public transport over long distances.

Fig. 8. Dimitrie Leonida Metro Station - bike & ride

This could contribute considerably to the changing behavior of the over-oriented inhabitants of the automobile, given that the option for modes of transport is influenced not only by costs but also by the comfort of travel. In the case of multimodal displacements, this parameter is also dependent on intermodal transfer conditions.

Application

An example of a trip to Bucharest
Origin: Ten Blocks Residential Complex (home)
Destination: South Market (Service)
Transport mode
Public-intermodal transport / personal car
Time 7:05
1. Walk + subway

- going from home to metro-subway station M3 - subway-metro M2-metro- from subway station at work

-time: 40 minutes
-cost: 2.5 lei

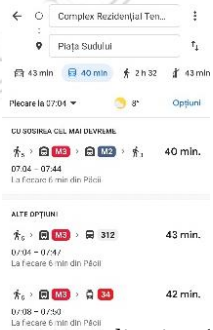


Fig. 9. The google maps application (a)

2. Walk + metro + tram

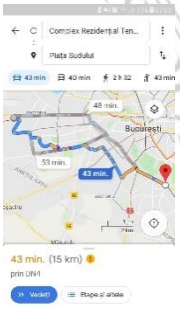
- walking from home to subway-metro station M3-subway-tram 34-change -walk from the tram stop at work

-time: 42 minutes
-cost: 3.8 lei
3. Walk + subway + bus

- going from home to subway-metro station M3-subway-metro M3-walking from bus station to service

-time: 43 minutes
-cost: 3.8 lei
4.Personal car (distance =10 km) - Monomodal transport (Dacia Logan; consumption 9 l / 100 km)

-time: 43 minutes
-cost: 10 lei



Time 7:20

Fig. 10. The google maps application (b)

1. Walk + subway

-time: 40 minutes
-cost: 2.5 lei
2. Walk + metro + tram

-time: 42 minutes

-cost: 3.8 lei

3. Walk + subway + bus

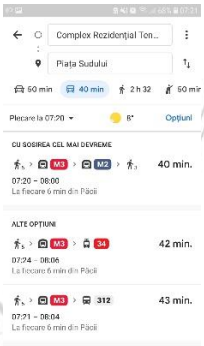


Fig. 11. The google maps application (c)

-time: 43 minutes
-cost: 3.8 lei
4. Personal car (10 km distance) - Monomodal transport (Dacia Logan, consumption 9.5 l / 100 km)

-time: 50 minutes
-cost: 11 lei

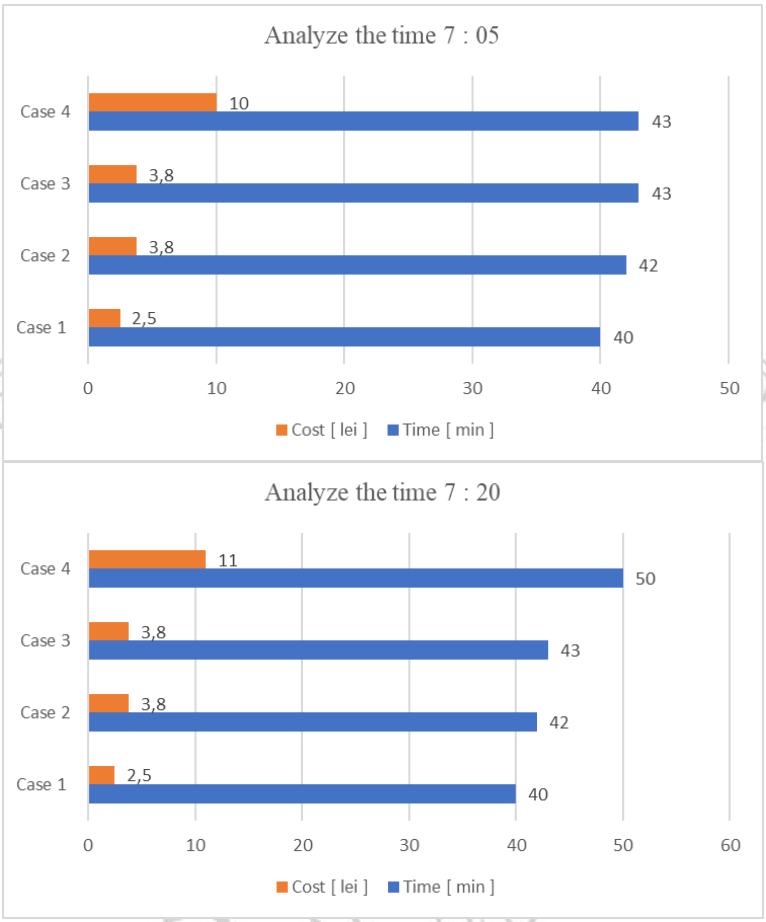


Fig. 12. Cost and journey time

The advantages of the intermodal journey in front of the passenger car travel are noticed by the major difference in cost and time of travelling (Fig. 12).

Conclusions

Intermodality is vital for a successful business in a city. It is not enough to find ways to respond to mobility by increasing the number of transport vehicles. Interdisciplinary solutions based on the link between transport and urban planning need to be identified through which spatial solutions related to transport development lead to a reduced need for mobility without suppressing users' access to services and activities, with non-motorized transport being more attractive.

With the increase in motoring, the Shanghai bicycle is increasingly being replaced by modern motorized vehicles. However, the bicycle is again taking its

place in transport in the city, especially for European cities, the result of co-motors with very negative external effects.

Encouraging reasonable bicycle modernization in cities is a key factor. The enormous number of motor vehicles is responsible for increasing the local economy; the reason why the bicycle plays an important role in balancing the public transport system.

Metro is a real asset in integrating urban public transport with other modes. So we can track the integration of urban transport and the use of non-motorized means. In addition, according to travel cost analysis, urban transport becomes more attractive than personal vehicles for longer journeys and non-motorized mode becomes more tempting than motorized vehicles for shorter travel times. Therefore, intermodal transport must undoubtedly be encouraged.

Integration of different modes of transport contributes to a more efficient and sustainable urbanization in reducing emissions of CO2 and noise pollution.

The analysis shows that the inclusion of public transport on journeys extends space accessible for all modes of transport and generates fewer emissions than passenger car traffic. Individual motorized traffic is faster and cheaper on very short distances, but they can be easily covered by bicycles.

Regarding the example of travel in Bucharest at the peak hour, the advantages of the intermodal journey in front of the passenger car travel are noticed by the major difference in cost and the time required for the trip.

R E F E R E N C E S

[1] Dragu, V. Rosca, E. Rusca Aura Public Transport -Feasible Solution for Sustainable Urban Mobility,Proceedings of the European Automotive Congress EAECESFA 2015, Vol. II, ISBN 978-3-319-27275-7, SpringerInternational Publishing Switzerland, pp. 419-429, 25-27 November 2015, Bucharest Romania ;

[2] *** Sustainable Urban Mobility Plan 2016-2030 – Bucharest-Ilfov ;

[3] EC, 2013; JRC, 2013; NODES, 2014; UN HABITAT, 2013 ;

http://www.eltis.org/glossary/intermodality

[4] Negulescu, M. H. Intermodalitatea, o prioritate pentru Bucureşti, în contextul crizei conomice • Urbanism. Arhitectură. Construcţii • Vol. 3 • Nr. 4 • 2012 •

[5] Yeh Chao-Fu -A study on feasibility of passenger intermodal transport in city of the developind world , 2008 ,CODATU XIII

[6] Gebhardt Laura a.o., 2017. Mobility, Transport and Smart and Sustainable Cities;

[8] Ivanov Catiușa, 2019 https://www.hotnews.ro/stiri-administratie_locala-22930970-10yearschallenge-pistele-biciclete-din-bucuresti-122-circa-10.htm ;

[9]Andrei, M., 2018. http://mi.etlbiz.com/intermodalitatea-sistemelor-de-transport-poate-fi-cheia-unei-mobilitati-eficiente/

[10]https://www.google.com/maps/dir/