Mobility and Public Transport Service: from Deurbanization to Decentralization

Valeriy Marunich, Oleksandr Melnichenko, Vitalii Kharuta

Abstract—The aim of the study is to demonstrate the methodology for improving commuter traffic in the context of the decentralization of transport infrastructure concept and on this basis to increase mobility and transport services for the rural population with generally accepted European social standards and guarantees.

Keywords—transport system, transport infrastructure, deurbanization, decentralization, rural population

I. Introduction

General problem definition and its relationship with important scientific and practical tasks.

The uniqueness of the Ukrainian communication and mobile problems is that no other country in the world has transferred transport system to a new social level of quality yet. This work should be preceded by a scientific program approach and a clear legislative framework. As for passenger transportations, our national experts have been doing some work on improving commuter bus transportation. But they solved only one or some problems without systematic approach [1]. So, the structure of demand for suburban transportation has not been investigated, because the problems of the particular region were solved and a wide implementation was not summarized. There was an attempt to analyze the results of suburban bus services based on their technical standards and operational parameters [2], and not dynamic but static traffic system was studied without considering patterns of passenger traffic flow.

Note that studying the impact of individual and public transport development on the economic characteristics of the transport system [3], foreign experts concluded that in suburban and rural areas a reduction of transport service means a reduction of buses or its complete termination, resulting in the need of walking to the nearest functioning route. As a result, most passengers prefer their own transport, which otherwise they would not buy. Thus, the relative cost of travel tends to increase. For example, in the UK there is a deurbanization tendency (urbanization - (from Lat. Urbanus – city) – the growing importance of cities for the development of society, which is accompanied with growth and development of urban areas, increasing the proportion of the urban population, the spread of urban lifestyle in a particular region, country, world), leading to the distribution of the working population habitats in a large area with low concentration. This may explain the fact that in recent decades the number of personal cars has increased almost 8 times, and the number of trips made by suburban public transport compared to the 60s decreased to 50%. This trend has meant that in England the family accounts for more than one car.

Nowadays functioning transport system of Ukraine where the level of individual transport density is much lower, taking into account imperfections of automotive manufacturing and transport complex [4], the development of public transport remains prioritized. After all, if the EU countries try to improve mobility with the help of wide application of deurbanization trends, in Ukraine the concept of power decentralization has been launched and takes practical shape, which is regarded as the transfer of significant powers and budgets of state agencies to local governments so that the bodies closer to the people, where such powers can be implemented most effectively, could have as much authority as possible. [5] As for the increased mobility of Ukrainian population, scientific and practical support for the implementation of the of transport infrastructure is urgent.

V. Marunich National Transport University, Kiev, Ukraine (e-mail: marunic@univ.kiev.ua)
O. Melnichenko National Transport University, Kiev, Ukraine (e-mail: melnichenko@ntu.edu.ua).
V. Kharuta National Transport University, Kiev, Ukraine (e-mail: kharuta_vitaliy@ukr.net).

Analysis of recent research and publications. Within the framework of the European Program, Transport White Paper 2011 issues of increasing mobility and transport services for the population occupy the top position.

The European Commission has adopted a plan of 40 specific initiatives over the next decade to build a competitive transport system that will increase mobility, remove major barriers in key areas, dramatically change Europe dependence on imported oil and will reduce carbon emissions in transport by 60% till 2050 [6].

These issues are important for Ukraine and are now at the stage of project and program development. In particular, the Supreme Council of Ukraine regulation of 08.31.2015 Number 656-VIII “About preliminary approval of the bill draft on amendments to the Constitution of Ukraine concerning the decentralization of power” in the Policy brief “Transport Policy of Ukraine and its approximation to EU standards" and” regarding the priority measures to overcome the crisis in the transport system of Ukraine, in other laws and regulations important theoretical and practical aspects on this issue need proper software and organizational and financial support [7-8].

Highlighting unsolved aspects of a general problem, which the article is devoted to. The absence of single system approach and methodology for improving bus transport in suburban mobility to enhance transport services for the rural population in the context of decentralization of transport infrastructure concept.

II. Simulated Annealing

The main part with full justification of scientific results. Scientists of National Transport University developed a system of methods for improving bus transport of commuter traffic. Its main elements are the modern information support, modeling and evaluation of existing transport infrastructure, design of transportation system, operational management of transport process and its economic security. It is proved that the principles of the system suggest that existence of the road network and its combination are defined with areas and quantities of passenger traffic flow when it is regulated by the intensity of bus traffic and the fees for transportation.

For example, the analysis of commuter route system in Zaporizhya region revealed that settlements are usually directly connected with district and regional centers, that is radial nature of transport links is distinctly evident. Determination of tariffs depending on the passenger traffic distance doesn't make it possible to use optimization models of urban transport system.

Let us consider fragmented options for the design of route system (Fig. 1). Thus, when considering the standard version (Fig. 1 a) there is possible connection of settlements O, K, P, C with ring route O-K-P-C-O or with radial routes O-K-P, O-R-O, O-C-O and some other combinations. In the fragment of Fig. 1. b the connection between settlements O and P is possible in terms of separate route O-K-P-O or the route with a stop at the point P, so the route is O-K-P-K-C-O.

Thus, justifying route system, the problem of selecting appropriate options of route formation arises. For this purpose economic and mathematical model of rational number of route determination on the minimum social costs criterion was proposed. It should, first of all, evaluate the time spent by passengers for waiting and travelling by buses. For convenience some options of the routes are given (Fig. 1) with the passenger traffic flow pattern. In this case, public service can be organized in four versions: the first route involves O-K, O-P, O-C; the second one is O-K, O-C; the third one is O-P, O-C; the fourth one is O-C. According to the distribution of passenger traffic flows based on the direction, technical and operational parameters of vehicles, it is necessary to identify the most appropriate version of the route system. For this the multicriterion problem is solved with the need to minimize the number of operated vehicles, and the time spent by passengers on waiting and travelling by bus.

Analysis of the route system from a social point of view, based on hours spent by passengers on waiting and travelling, is carried out using the following ratio:

$$\Big(\sum_{N^{//}} \Pi_i^{//} t_{iwait.}^{//} + \sum_{N^{///}} \frac{\ln_i}{V_{ci}}\Big),$$
$$\Big(\sum_{N_i} \Pi_i t_{iwait.} + \sum_{N_i} \frac{\ln^i \Pi_i}{V_{ci}}\Big). \quad (1)$$

where: Π_i is the passenger traffic flow on *i* route; $t_{iwait.}$ is the time spent by passengers waiting on *i* route, hours; $\ln_i$ is the average distance of travel on *i* route, kilometers; V_{ci} is the speed of communication on *i* route, kilometers per hour; $^{//}$ are the indices appropriate for route systems that are analyzed.

It is possible to analyze the dependence of social costs on the number of commuter routes, using economic and mathematical model that takes into account running costs and level of transport services.

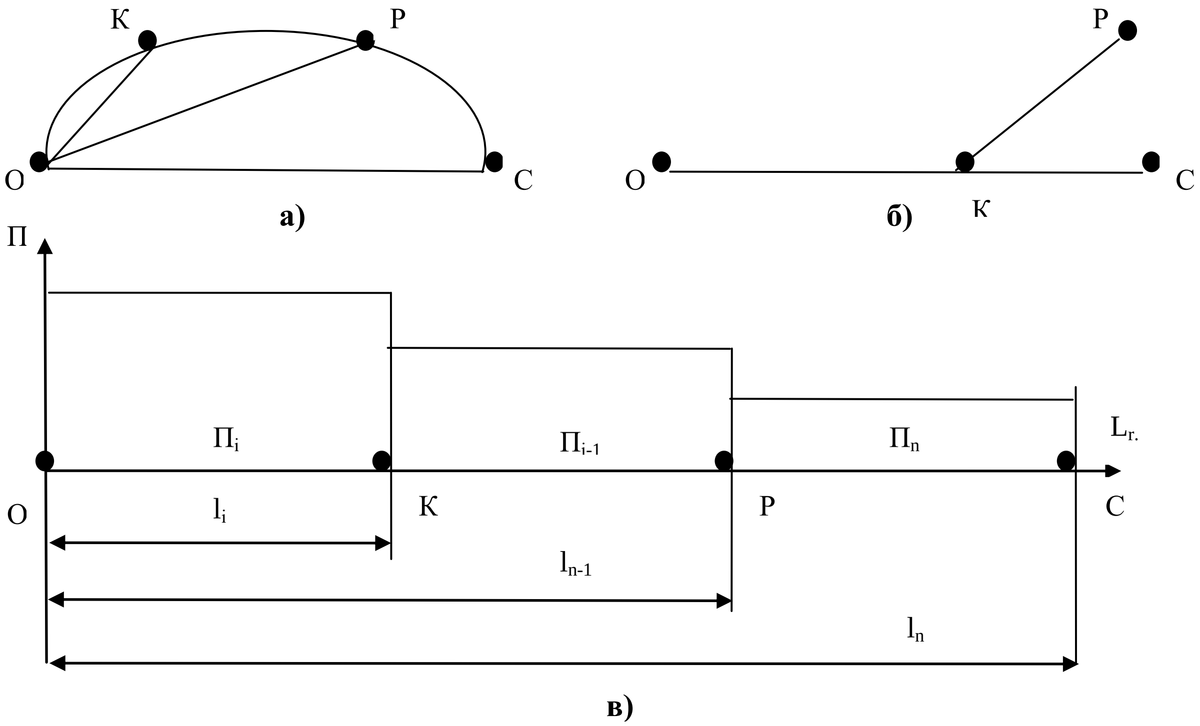


Fig. 1 – the graph of transport network and the diagram of passenger traffic flow on commuter routes: a) b) – the typical options; c) – generalized chart of passenger traffic flow distribution

To build economic and mathematical model we used baseline data and calculation standards. First of all, they include information about the size and distribution of passenger traffic flows, structure and characteristics of the route system, the speed of communication, characteristics of station and road network, type of vehicle and so on. Economic and mathematical model determines the number of routes depending on the estimated number of routes. Logistics construction of such model allows for a wide range of routes in definite directions with different transportation capacity and with any correspondence of passenger traffic flow depending on the social costs, part of which is directly proportional, and some inversely proportional to the number of routes. This makes it possible to define a minimum social costs that meet the optimal number of routes. Economic and mathematical model is as follows:

$$E_м = \frac{C_1}{N} + \frac{C_2}{N} + \frac{C_3}{N} + C_4 N + C_5 N + C_6 N + C_7 N \,, \quad (2)$$

where: C_1 is expenses for fueling and oiling, wearing and tire repair, hryvnas; C_2 is running costs, expenses for maintenance and repair of vehicles, hryvnas; C_3 is expenses for drivers' and conductors' salary and wage, hryvnas; C_4 is the costs of bus stops including forward and reverse directions, hryvnas; C_5 is the time spent by passengers waiting for buses and going by them, hryvnas; C_6 is the costs for reconstruction and maintenance of roads and bus stations, hryvnas; C_7 is the costs of travel for a fee, hryvnas; N is the number of routes, numbers.

Solving the problem of extreme searching for a minimum cost function of the route number is reduced to differentiate the above equation for N , that means that:

$$\frac{E_м}{N_м} = \frac{C_1}{N^2} + \frac{C_2}{N^2} + \frac{C_3}{N^2} + C_4 + C_5 + C_6 + C_7 \,, \tag{3}$$

or,

$$C_1 + C_2 + C_3 = (C_4 + C_5 + C_6 + C_7) N^2 \,, \tag{4}$$

so,

$$N = \sqrt{\frac{C_1 + C_2 + C_3}{C_4 + C_5 + C_6 + C_7}} \text{, routes.} \tag{5}$$

The following economic and mathematical model is implemented under conditions of dynamic information change on demand for transport. This approach is sufficient to account for the features of the complex object, which is the suburban bus transport system.

The model built in the information complex of technologies and ways of bus transportation management in suburban traffic.

The investigation of relationship between the commuter routes number and transportation process (Fig. 2). found that with increasing capacity of passenger traffic flow and length of routes their number increases. And with the increasing cost of one passenger hour the required number of routes is reduced.

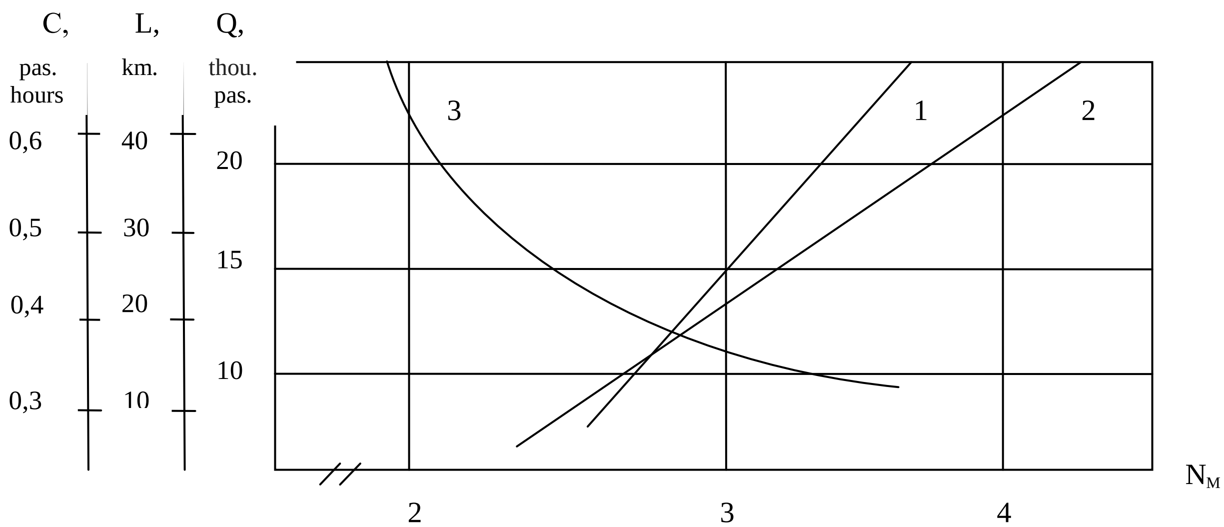


Fig. 2 — the graph shows number of routes 1 — passenger traffic flow capacity; 2 — the length of routes; 3 — passenger hours

III. Low Shop Problematic

The research of implementation of improving commuter traffic methods was carried out on the example of Zaporizhya region. Almost for the first time a comprehensive study of the passenger correspondence matrix method use took place in 16 districts of the region during four specific days. 147 inner-suburban and 87 intercity routes were examined. The computer processing required about 560 000 Kb of RAM. Background information was the basis for the analysis of transport services. For example, in the Melitopol district of 70 settlements (1 town, 1 urban village and 68 villages) with the number of inhabitants of about 240 thousand 23 intra-suburban routes operated, covering 91% of the populated areas in the district. Only 3 thousand people living in 6 settlements are not covered with transport. According to these characteristics the level of public service is satisfactory, but the shortage of fuel resources and the availability of vehicles does not allow the system to operate in the required mode. In this respect, because of the available resources, some recommendations were elaborated to involve optimization of suburban routes from 23 to 18 and the number of travels from 145 to 132 per day. This became the basis of the fuel and financial balance, which determined that for the optimal organization of transport it is necessary to provide monthly fuel provision of 18.1 thousand liters of petrol and 17. 2 thousand liters of diesel.

Computerization and automation of solving these problems of improving commuter bus transportation reduced the complexity and performance, and the dynamic simulation model of transport system was received. Thus, the given research shows the urgency of commuter traffic improvement and requires further scientific methods of solving them.

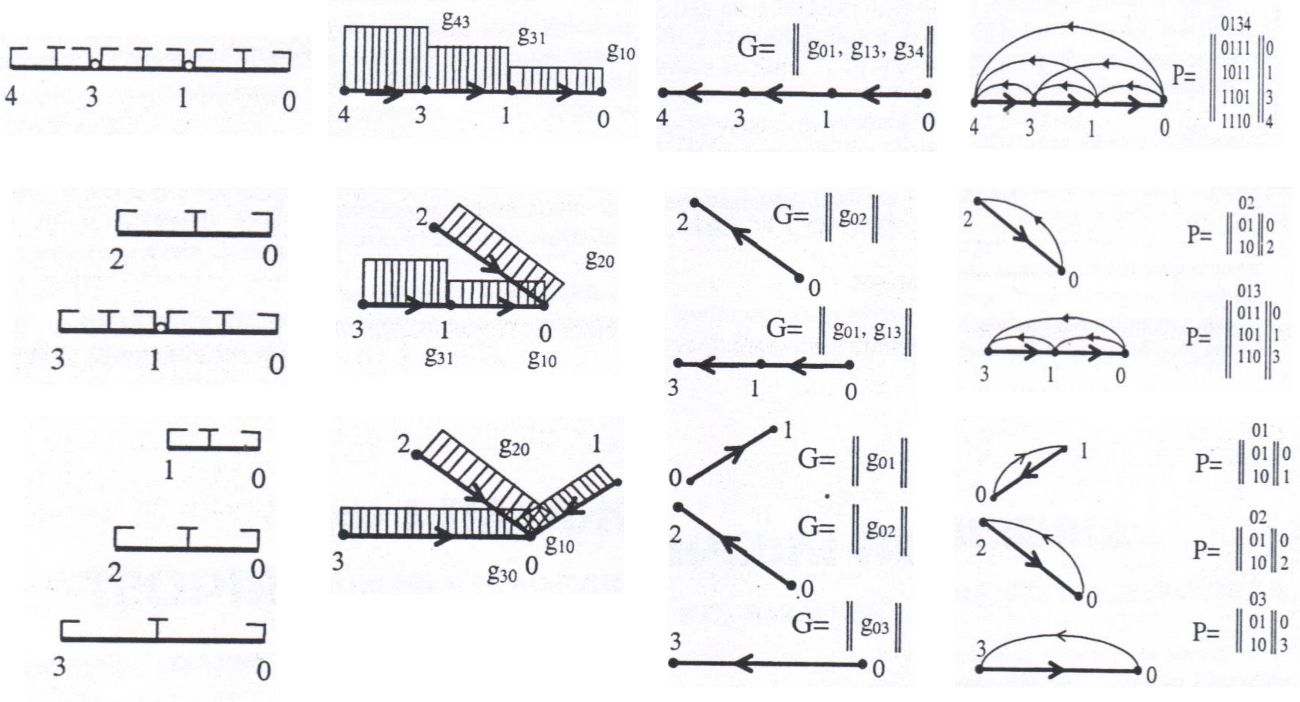
IV. Methods

Moreover, studies of the optimal route construction for the commuter routes using the theory of graphs, found that one and the same set of transport network connections can be served by different number of buses, that makes us focus on the passenger time distribution, which means the formation of traffic schedule using Gantt charts and Bayesovskyi methods, etc. (Table. 1).

TABLE 1

The graph and matrix of transport links for route system in time (including range of motion)

Transport network fragment (Gantt chart)	Variations of transport links	Graph and matrix of transport links	Graph of transport network based on adjacency matrix



Statement: one and the same known number of travels may be served by different number of buses

V. Results

The conclusions of this study and further research conducted in this direction. Implementation of the proposed developments in the Zaporizhya region allowed: to set up transportation according to demand and considering resources provision, thus the mobility of the rural population was significantly improved; to streamline the route system, making it possible to reduce the number of routes from 221 to 150 while reducing daily volume of buses; to increase speed of public transport connection by 10-15%; to decrease fuel consumption of passenger transportation by 25% and to reduce emissions of harmful substances into the environment by 15%.

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