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Enhancing effectiveness of use of the rolling stock through route optimisation

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The article deals with issues of enhancing efficient use of the rolling stock of urban passenger transport through route optimisation. The authors offer to upgrade urban route network opt for: optimisation of routing system. In order to streamline passenger transport performance, the authors propose to calculate transport route schemes by applying economically mathematical methods of planning.

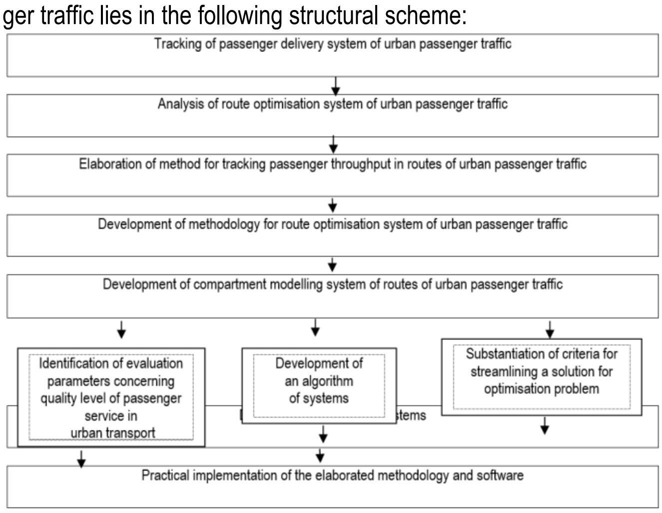
Wstęp

The conducted analysis of current state of passenger traffic shows mismatch with up-to-date requirements towards passenger traffic quality [1]. Travel time often does not correspond to the established standards, which can be explained by low speeds of main types of transport (buses, trolleybuses, trams), necessity to transfer or interchange routes due to incomplete route network and time lost in approaching the stops. Travels during peak hours feature uncomfortable conditions due to breach of established standards of passenger capacity allowed in the rolling stock. Hence, optimisation of the route network of urban passenger transport is currently problematic.

There is a significant amount of scientific papers [1, 2, 3, 4] elaborated on streamlining the urban bus routes and transport in general. Meanwhile, as the experience shows, routes cannot be planned basing on mathematical calculations alone. Traditions, habits, ecological and other factors have to be considered, Unavoidable deviation from calculation models lead to failure of the calculated route system as such. Therefore, no optimum routing scheme has been introduced in real life. In this article we have attempted to bypass contradiction between theoretical models and real possibilities.

1.Main Section

The proposed work at streamlining the system of urban passenger traffic lies in the following structural scheme:



To provide a good quality passenger service with minimum quantity of transport and to enhance efficiency of passenger traffic, one can improve use of the existing fleet through streamlining the urban passenger transport

Transportation of people is a complex social phenomenon, gaining its momentum from many diverse factors. It embraces: level of development of social production, lifestyle pattern, social structure of public, geographical environment and nature of settlement, cultural and social and public demands and so on. One cannot develop optimum versions of transport services without delving deeper into these issues and problems.

Nowadays route systems are, to a great extent, calculated and built separately, not taking into account the needs of an urban route system as whole. Therefore, one can see high rate of passenger transfer, which in its turn leads to permanent adjustment and changes in the established routes.

When streamlining an operation of the passenger traffic, we propose to apply economically mathematical methods of planning. We assume that eventually it will have a significant economic effect. Accordingly, it reduces travelling costs, improves public service quality and workforce productivity. When solving this task, it is possible to build the route network more correctly, determine the starting and ending point of travel, choose type of the rolling stock, calculate traffic intervals by periods of day-and-night and the required number of the rolling stock by routes. Solving of present task will enable the maximum service quality of transporting with the existing fleet and dividing them by routes. Since use of urban passenger traffic is related to, firstly, saving of time spent on travel, the most important indicator is time spent on travel alone.

The article offers to calculate schemes of bus routes by economically mathematical method [2] The method is based on progressive calculations. The essence of the task is as follows. We know time of bus movement along each section of the transport network. We know the scope of passenger throughput between the points of given transport network, classes, types, number of units, brands of the rolling stock, their technical and operational features, which will be used to service the given lines. Volumes of passenger throughput between points of given transport network are determined. Type of transport means, servicing the contemplated lines, is chosen. One needs to determine a scheme of transport routes that would allow minimising the number of the rolling stock in the lines [3].

The following restrictions apply to the solution: capacity of the buses applied must not be lower than the proposed coefficient; length of a route must not be less than the minimum and not more than maximal length, given in advance.

2.Calculations

With a view on previously stated factors determining the number of passengers, we will identify the number of rolling stock in motion necessary to ensure transport process to come up with different versions of transport services according to formula:

$$N_{дв} = \frac{P}{365 * V_э * m * h * \eta} \qquad (1)$$

(machines/wagons),
where:
P – output of transport (pass. km/year),
m - capacity of the rolling stock,
$V_э$ - cruising speed (km/h),
h - number of working hours of transport in the line,
η - fill factor of the rolling stock

In the example statistical data of a typical city with population of 1,000,000 persons were taken. P – 5 569 200 passengers per year for a tram. P – 5 164 800 passengers per year for a trolleybus. P – 4 733 600 passengers per year for a bus [4].

Tab. 1. Output data for calculations

Transport type	Overall performance			
	$V_э$	m	h	η
Tram - 1	15	126	14	0.35
Trolleybus - 1	15	70	14	0.35
Bus - 1	19	60	13	0.3

Calculations are made by Mathcad for different types of urban passenger transport:
For trams:

ORIGIN:=1

k:=1..3 i:=1..7 j:=1..3

$$P := \begin{pmatrix} 5\,569\,200 \\ 5\,164\,800 \\ 4\,733\,600 \end{pmatrix}$$

$$V := \begin{pmatrix} 15 & 20 & 25 \\ 23 & 28 & 30 \\ 33 & 35 & 38 \\ 40 & 43 & 45 \\ 48 & 50 & 53 \\ 55 & 58 & 60 \\ 63 & 65 & 70 \end{pmatrix} \quad h := \begin{pmatrix} 6 \\ 8 \\ 10 \\ 12 \\ 14 \\ 16 \\ 18 \end{pmatrix} \quad \eta1 := \begin{pmatrix} 0.10 \\ 0.15 \\ 0.20 \\ 0.25 \\ 0.30 \\ 0.35 \\ 0.40 \end{pmatrix}$$

$$\eta2 := \begin{pmatrix} 0.05 \\ 0.10 \\ 0.15 \\ 0.20 \\ 0.25 \\ 0.30 \\ 0.35 \end{pmatrix} \quad \eta3 := \begin{pmatrix} 0.02 \\ 0.05 \\ 0.10 \\ 0.15 \\ 0.20 \\ 0.25 \\ 0.30 \end{pmatrix}$$

$$m1 := \begin{pmatrix} 50 \\ 60 \\ 70 \\ 80 \\ 90 \\ 100 \\ 130 \end{pmatrix} \quad m2 := \begin{pmatrix} 20 \\ 30 \\ 40 \\ 50 \\ 60 \\ 70 \\ 80 \end{pmatrix} \quad m3 := \begin{pmatrix} 15 \\ 20 \\ 30 \\ 40 \\ 50 \\ 60 \\ 70 \end{pmatrix}$$

$N1_{i,j}:=P1/365*V_{i,j}*m1_i*h_i*n1_i$

$$N1_{i,j} := \begin{pmatrix} 33.907 & 25.43 & 20.344 \\ 9.214 & 7.568 & 7.064 \\ 3.303 & 3.114 & 2.868 \\ 1.589 & 1.478 & 1.413 \\ 0.841 & 0.807 & 0.762 \\ 0.495 & 0.47 & 0.454 \\ 0.259 & 0.251 & 0.233 \end{pmatrix}$$

For trolleybuses:
$N2_{i,j}:=P1/365*V_{i,j}*m2_i*h_i*n2_i$

$$N2_{i,j} := \begin{pmatrix} 157.224 & 117.918 & 94.334 \\ 25.634 & 21.057 & 19.653 \\ 7.147 & 6.738 & 6.206 \\ 2.948 & 2.742 & 2.62 \\ 1.404 & 1.348 & 1.271 \\ 0.766 & 0.726 & 0.702 \\ 0.446 & 0.432 & 0.401 \end{pmatrix}$$

For buses:
$N3_{i,j}:=P1/365*V_{i,j}*m3_i*h_i*n3_i$

$$N3_{i,j} := \begin{pmatrix} 480.325 & 360.244 & 288.195 \\ 70.482 & 57.896 & 54.037 \\ 13.1 & 12.351 & 11.376 \\ 4.503 & 4.189 & 4.003 \\ 1.93 & 1.853 & 1.748 \\ 0.982 & 0.932 & 0.901 \\ 0.545 & 0.528 & 0.49 \end{pmatrix}$$

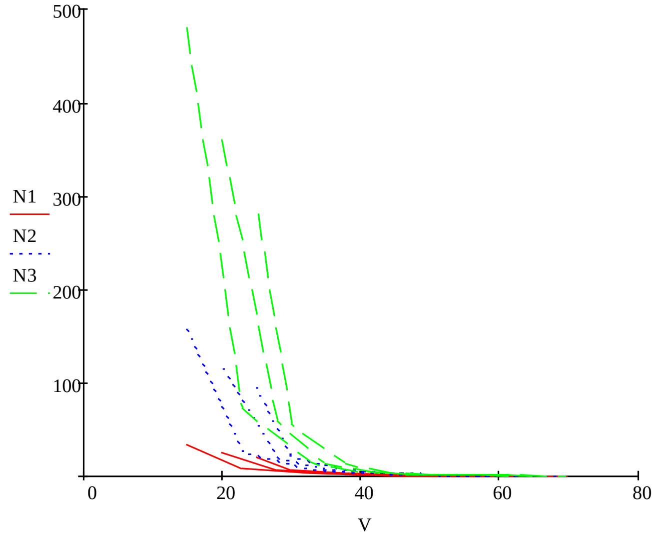


Fig. 1.

To begin with, we built a graph based on the data that Mathcad calculated.

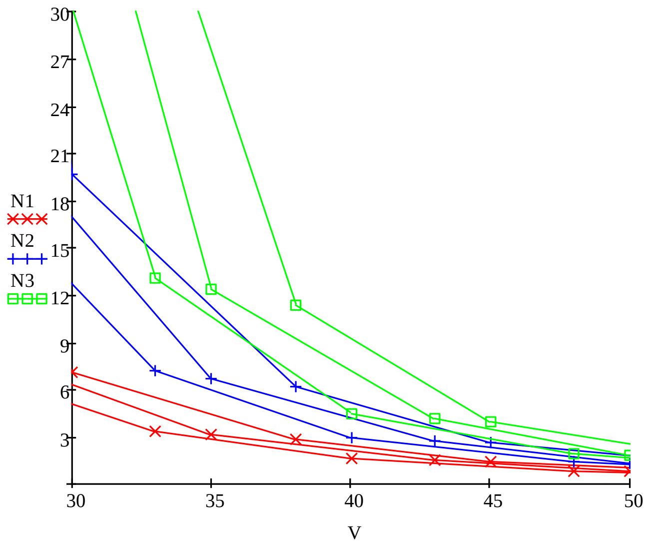


Fig. 2.

And then they took a speed mode from 30 to 50 to see the graph more clearly. Proceeding from the given data, we clearly see that the speed of the rolling stock should be increased. It would enhance the efficiency of transport performance.

Conclusion:

Consequently, the authors assume:

– Introduction of a new scheme allows reducing the number of trams and buses, considering the real rate of release of certain brand, reducing a need for the rolling stock in a city, making it easier to reduce the financial burden on the city budget.
– Distances of the calculated route networks amount to 766.77 km for cities with population of 1,000,000 persons. In the existing route network that value is approx. 985.08 km.
– Social effect in terms of less time spent on waiting, travel and transfer is achieved by using a volume capacity not less than the contemplated one, manifesting as reduced pollution of environment from flue gas of the bus fleet.

Optimisation of routes of urban passenger transport, i.e. switching to a new transport network must have a significant effect during peak hours in a work day given the same number of transported passengers.

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