THE NEW APPROACH TO OPTIMIZATION OF THE PUBLIC TRANSPORT ENTERPRISES NETWORK IN HANOI

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Summary: *In the article application of queuing systems model in the field of operation of motor transport is presented. The system of maintenance service (MS) and operating repair (OR) of the cars on technological base is considered as multichannel multiphase queuing system. The mathematical model allows to receive necessary parameters of system MS and OR and to optimize them on technical-economic criterion.*

Keywords: *queuing system, Hanoi, Vietnam, municipal public transport, maintenance, network of bus technical services, bus fleet of a city.*

Introduction

Currently, in the Socialist Republic of Vietnam (SRV) road transport is booming. One of the main modes of transport engaged in passenger transportation is the bus. In 2013, 54 out of 63 provinces across the country have a public transportation system that includes more than 615 routes, 8253 units of transport, including Hanoi - more than 1,300 units [1] (Figure 1, 2).

At the new stage of socio-economic development of Vietnam, the system of public passenger transport in major cities, especially in Hanoi plays a very important role.

This system may evolve, not only through the organization of the route network, but also due to the improvement of the production activity of the passenger transport enterprises. In 2004 was established the state unitary company of road transport of Hanoi "Transerco", which handles the bulk of routes, including 86 bus routes,- 79 urban and 7 suburban routes. In addition, there were organized several private transport companies. The city continues to grow, which is accompanied by a steady increase in the number of inhabitants and therefore increased demand for transport and increase the number of buses [1].

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Hanoi city has a high population density, and the road system in the Central part of the city was built long ago, the streets are relatively short, narrow and have many intersections. Despite of the residents use small personal vehicles, such as bicycles, motorcycles (and cars too) during peak hours traffic jams often are formed.

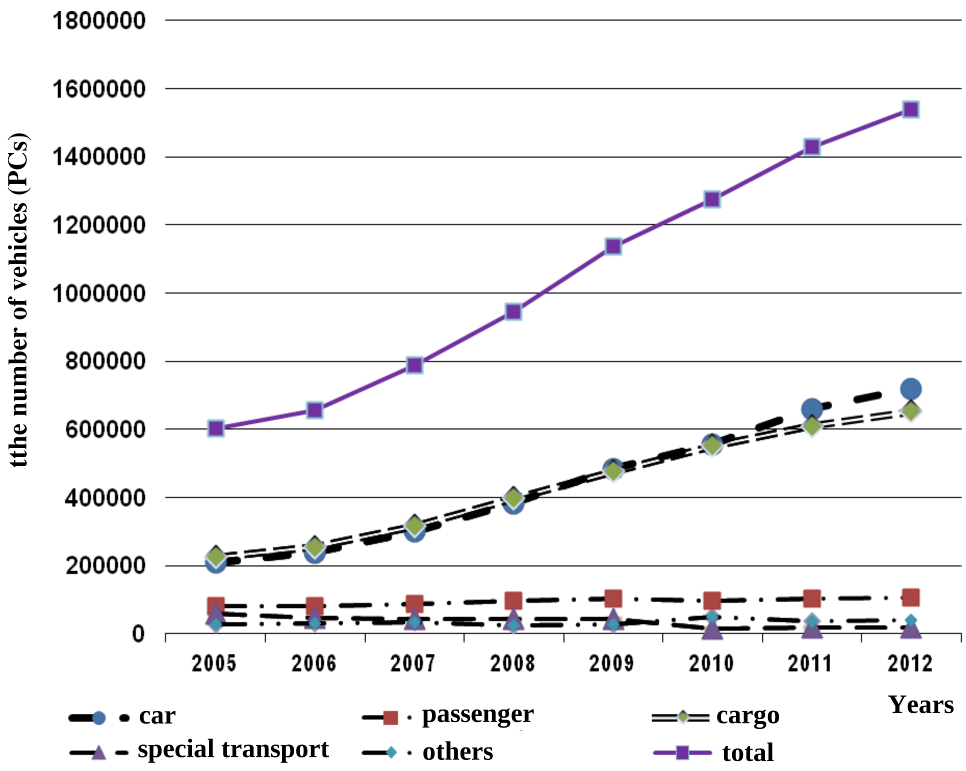

Fig 1. The growth in the number of vehicles by type of transport in Vietnam

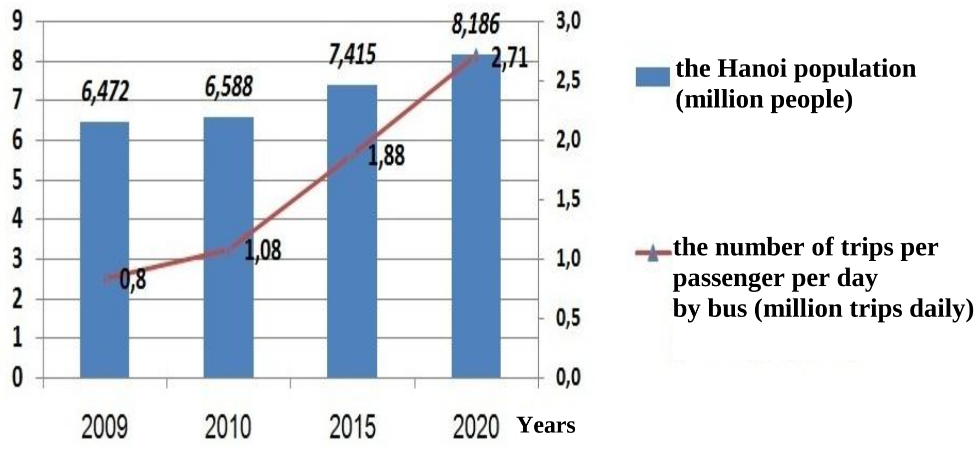

Fig 2. *Forecast of population increase and demand on transportation in Hanoi*

Demand for the use of public transport among residents significantly increased, buses are often overloaded.

The average speed of the bus on the street is very low, about 20-22 km/h. This means that coaches often work in busy mode, in addition, in the structure of the bus fleet of the city dominated by cars with high mileage, so failures and malfunctions occur in the operation of buses on the line. The elimination of buses failures is carried out on line or at a motor transport enterprise (MTE). However, while waiting for transfer the bus to MTE for repair, it remains on the roadway, which can cause jams and affect the movement of other vehicles. All this leads to a decrease in operational efficiency and performance of vehicles, as well as a direct impact on the profits of enterprises.

Main

In view of the above, the role and importance of technical base of MTE in providing high quality and safe passenger transport is roused. Its main task - to ensure the required level of technical readiness of vehicles, safety of road transport and reduce environmental pollution. Operating costs in the performance of passenger transport buses remain significant, but can be reduced by improving the efficiency and quality of maintenance (MOT) and a current repair (technical service - TS) in production-technological base (PTB) of public transport companies. Practice shows that in these Hanoi enterprises are the following problems: the lack of production areas; misallocation of work stations in production areas; the absence of certain types of manufacturing equipment, etc. In some small companies process MOT and TS is not performed in accordance with established standards and requirements, so it is difficult to control the quality of work performed. All this affects the technical condition of the vehicle, as well as traffic safety and the environment.

For the purpose of increase of efficiency of activity of PTB, serving municipal public transport fleet in Hanoi, were examined various approaches.

Since the network bus fleets mainly consists of small enterprises, improving the efficiency of repair stations achieved, as a rule, (in addition to improving production discipline) the creation of special posts for some types of vehicle failures, cannot be realized in view of low load of these posts insufficient for their economic efficiency. At the same time, the specialization of TS ahd MOT work is one of the most important tasks, because it leads to increased productivity, quality of work, leads in General to lower labor and material costs to maintain the technical condition of the fleet at the required level. Consolidation of enterprises would allow the organization of specialized posts, however, due to high-density buildings and businesses in the city of Hanoi to expand the PTB, the area is only possible for a small number of bus enterprises and in a small range.

In this regard, for the task it was formulated an approach in which the entire public transport network of the PTB as a whole is regarded as a system of mass service(queuing system), both multi-channel multi-phase system (QS). Thus created on some (major) companies specialized posts perform repairs not only for "their" bus, but for vehicles with other companies. This ensures a sufficient loading of such posts. The number and range of types of specialized posts, as well as enterprises that can effectively participate in the program of distribution and resource-sharing throughout the system is determined in the course of finding solutions for mathematical models of the functioning of this QS.

Network of enterprise's PTB (small and major) can also be represented as consisting of separate subsystems, which differ in nature, size, and organization of work. The task of this network is to create all conditions for the effective operation of the PTB individual enterprises, while providing time savings, eliminating time lost, reducing the number of failures on the line and reduce costs of TS rolling stock. The effective functioning of a network of enterprises depends on the quality of its subsystems (PTB), for which you can create the best working conditions, providing them with appropriate facilities. However, the optimal independent functioning of separate subsystems (PTB) does not mean that the entire network will also work in the optimal mode. Malfunctions of individual subsystems due to excess incoming flows requirements on bandwidth capabilities or the lack of specialized types of work (on TS) leads to unproductive downtime of buses, the increase in the number of failures on the line, and therefore loss of working time of buses.

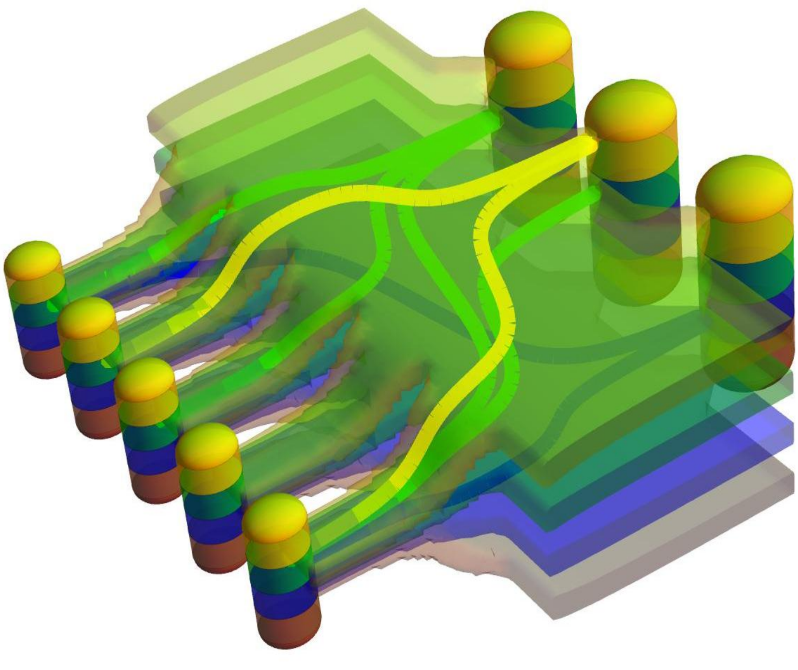

Fig. 3 *- Scheme of the separation of requirements flows on the TS system in network PTB of passenger transport companies as the QS*

Thus, for the analysis and research the enterprise network require perfect mathematical model allowing to properly take into account all the features of the network, including the interaction of subsystems, the influence of external related factors influencing it. To build such a model can be used queueing theory (with constraints implemented during actual operation of buses and the organization management system). To find the rational structure of the whole system and its constituent subsystems was created criterion for assessing the effectiveness of the entire enterprise network.

QS in the bus repairing area is characterized by the following elements: input flow requirements - the flow of failures to the system of TS; queue - requirements for the repair of vehicles awaiting service; work posts in the system MOT and TS; output requirements flow, leaving the system.

Systems in which random moments are the admission requirements for the services and duration of the services, are called queuing systems.[2] System of TS on each of the small public transport companies can be considered as a multi-channel QS, including "n" posts (in this case - universal positions), without limitations of waiting in line or waiting time.

At the same time, for Central (main) enterprises the structure of the QO is represented as a multi--phase, in which the entire flow of incoming requests is separated into several channels - universal posts channel and the channels of specialized posts.

Schematically communications companies failure flow is shown in figure No. 3, where different colors indicate "layers - guides" for the flows of different specializations of failures, but not necessarily every small business redirects specials. flows to major failures. Here the company shows as layered cylinders, and small enterprises - in the left side of the figure, and the main - on the right side.

The criterion of efficiency of created structure is determined by the generalized objective function:

$$C_{\Sigma}(\mathrm{n_{ij}}, \mathrm{n_{ij0}}, v_{il_{TO}}, v_{ijl}) = C_{pr_{\Sigma}} + Z_1 + Z_2 + Z_3 + Z_4 \quad (1)$$

where:

- $C_{pr\Sigma}$ - component determined by the costs of working and non-working posts in enterprises, as well as on buses staying at posts and in queue,

- Z_1 - component determined by the movement of buss to a parent(main) enterprise for work on MTO /due to the loss of time and fuel/,

- Z_2 - component determined by the difference between the moving buses (or removed units) to a parent(main) enterprise instead of having repairing work on its own enterprise / due to the loss of time and fuel/,

- Z_3 - component, defined capital costs for the creation/upgrading of posts,

- Z_4 - component defined by the reduction in the value of the stored spare parts /specific to the average time of turnover/,

v_{ijl} – the part of failures of type "j" from the company № *i* sent to the main company № *l*,

$\nu_{il_{TO}}$ – the part of maintenance work from the company № *i* sent to the main company № *l* ,

n_{ij} – taken number of posts of «j»-th specialization on the enterprise № «i»,

n_{ij0} – start number of posts of «j»-th specialization on the enterprise № «i».

The component of the objective function determined by the cost of operation and simple posts in enterprises, as well as a idle time of bus at the posts in the queue is presented in the form of:

$$C_{pr\Sigma} = \sum_{i=1}^{N}(n_i - \rho_i)*C_1 + \sum_{i=1}^{N}\rho_i * C_2 + \sum_{i=1}^{N}(r_i + \rho_i)*C_3 + \\ + \sum_{i=1}^{M}\left(\sum_{j=1}^{k_i}(n_{ij} - \rho_{ij})*C_{1j}\right) + \sum_{i=1}^{M}\left(\sum_{j=1}^{k_i}\rho_{ij} * C_{2j}\right) + \sum_{i=1}^{M}\left(\sum_{j=1}^{k_i}(r_{ij} + \rho_{ij})*C_3\right) \quad (2)$$

where:

N - the number of "small" ATP with universal posts,

M - the number of "major" ATP with universal and specialized posts,

k_i - number of channels (specializations) in a queuing system - i-th main enterprise,

n - the number of posts in the company (the index "i") or at the j-th specialization on the i-th major ATP,

ρ - the minimum number of posts in the company (the index "i") or at the j-th specialization on the i-th major ATP,

r - average queue to the universal posts or for the posts of specialization.

The coefficients of proportionality for the idle, replacement posts of each type (C1) are determined by the costs, including the salaries of workers employed in positions of this type of unit (per unit time) equipment costs post (cost of the equipment divided by the normalized, average service life), the cost of the works to maintain health post and the equipment for the same time unit. The coefficients of proportionality for the working stations (C2) further include the costs of the operation of the equipment, the cost of electricity, the accompanying materials, etc. Cost factor C3 sets the loss of the component of the objective function, which is determined by the total average number of vehicles temporarily "switch off" from the operation - idle in the queue, on posts, in line downtime, additional bus moving to main enterprise company. Usually, when dealing with such systems, the costs associated with the necessary and redundancy stay in the car repair and waiting for repair, estimates the lost income, definable specific rate per unit of time with one car running on the line. However, for this problem, when we are dealing with a system which must fulfill certain amount of work, this version of the assessment (part of component CprΣ) is not suitable. The approach formulated in this paper is that we take into account that in order to maintain the reliability of the system the municipality should acquire more or less (in the case of improving the quality and performance of repair work), the number of buses.

After construction of the objective function for costs of the TS bus network of enterprises, which includes the maximum possible number of components that take into account the possibility of changes in the number of posts for specialized activities of TS on major companies, it is necessary to optimize it. Optimization the solution of this task takes into account the redistribution of types of specialized works on TS between small and major enterprises. It was necessary to find a rational approach to certain assumptions to solve the above problems:

- selecting those companies that will be considered as the main, they will be converted under the posts specialization and create new positions;

- in the analysis and processing of statistical data on repair works at PTB in the enterprise network were defined some groups of TS work within which it is possible to allocate repair of complex and small. While the number of specializations for which it makes sense to focus on the main enterprises, may vary, and theoretically each of the main enterprises can be organized to hold several types of specialized works, although in terms of scale of enterprises of Hanoi seems rational organization of no more than one type of custom posts into a main enterprise;

- determined the possible number of specialized posts by major companies depending on the maximum possible demand for such positions. It may be noted that most of the posts are occupied by the performance of maintenance work (in all enterprises), and a few repair posts, therefore, the creation of specialization on buses maintenance at any major enterprise is impossible due to the fact that the creation of additional quantity of posts on any of ATP of Hanoi has not enough space

- The approaches to the search for the optimal redistribution of subflows of failures from small to major enterprises. Can be distributed the priorities among of small enterprises and the possible limits for specialized sub-streams moves to the major enterprises.

Each component of the objective function is a function of both the redistribution of flows repairs among enterprises, and the number of posts of various specializations in the enterprises.

The intermediate parameters, such as length of queues, downtimes in the queue, etc. are calculated by the formulas of queuing theory. These formulas include also dependence on improving the quality and performance of repairs after the repair work on specialized posts, which is expressed by formulas such as:

- for small enterprises:

$$\rho_{ij-n} = \rho_{ij} \cdot (1-\sum_{l=1}^{L_{ij}} v_{ijl}(1-q_j)) \cdot (1-\sum_{l=1}^{L_{ij}} v_{ijl}) \cdot \left(1-\left(\sum_{l=1}^{L_{ij}} v_{ijl}\right) \cdot \frac{\xi_j - 1}{1-\theta_j}\right) \qquad (3)$$

- for major enterprises:

$$\rho_{ijl-n} = \rho_{ij} \cdot \frac{(1-v_{ijl}(1-q_j)) \cdot v_{ijl}}{u_j} \cdot \left(1+\frac{\xi_j - 1}{1-\theta_j} - \sum_{l=1}^{L_{ij}} v_{ijl} \cdot \frac{\xi_j - 1}{1-\theta_j}\right) \qquad (4)$$

here:

ρ_{ij} – given density of the flow failure (the average number of occupied positions in the framework of the adopted model) TP specialty type 'j' in the enterprise with the number 'i' (sub-stream 'ij') before the reorganization,

ρ_{ij-n} – the average number of occupied posts (substream CijT) after the reorganization, remaining in a small enterprise № 'i',

ρ_{ijl-n} – the average number of posts specialization type 'j' in the major enterprise number '*l*' (substream 'ij', sent to the company '*l*') after the reorganization,

ξ_j – the average value of the duration of the fault fixing in full "heavy" substream 'j', which includes those faults which can be eliminated in specialized positions with high efficiency,

θ_j – the proportion of failures relating to a full "heavy" substream with an average duration of elimination ξ_j ,

v_{ij} – share (of source) stream that is sent to eliminate the failure to specialized posts,

q_j – the quality factor that determines the decrease of the flow of failures (return value - increasing mean time between failure) on those vehicles, the repair of which is held on specialized posts,

u_i – factor determining the change in intensity of the recovery of the bus on the special positions in relation to the work on universal posts.

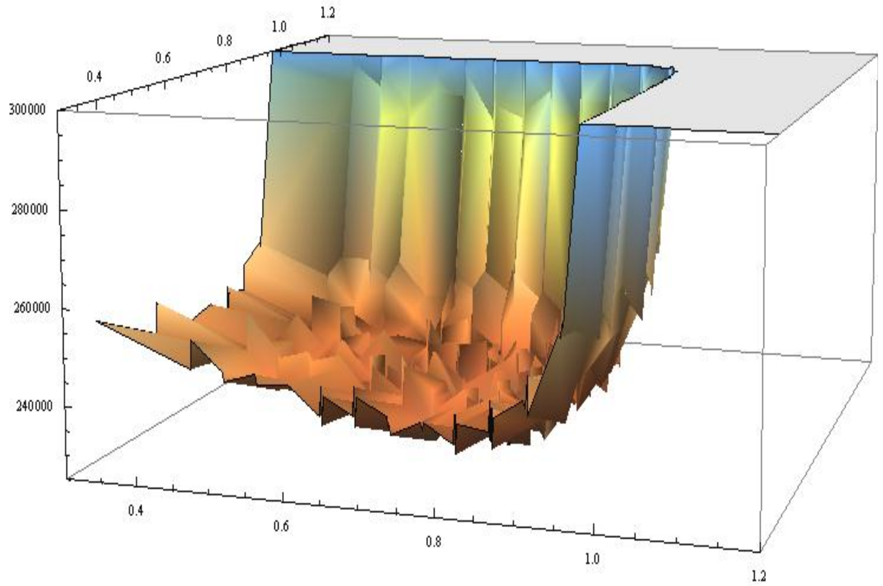

Fig. 4. *An example of the results of the calculation of the objective function of the model.*

Figure 4 shows a variant of the calculation model, carried out with two types of specializations repairs and variations set of small enterprises connected to the network program specialization. Sets of connected companies in each specialization is characterized by a given density of the flow failure and are shown on the axes argument.

The calculation of the average number of applications awaiting the passage of the repair (length of queues), is carried out for individual channels according to formulas of the type:

$$r_i = \left(\left(\frac{n_i - \rho_i}{\rho_i} \left(1 + (n_i - 1)! \cdot \frac{(n_i - \rho_i)}{\rho_i} \cdot \sum_{k=0}^{n_i - 1} \frac{\rho_i^{k+1-n_i}}{k!} \right) \right) \right)^{-1} \quad (3)$$

Where in formula parameters have the same description as in the formula (2).

Finding an optimal structure for specializations, the number of posts and the reallocation of repair work is carried out by variation of all input variables by a special algorithm.

Conclusion

Using the above mathematical model of a network of public transportation enterprises, with the known data of the existing enterprises in Hanoi, we can get the following results:

- Varying the values of parameters entering into the above model, we can determine the structure of the network and its member companies so as to obtain the minimum value of the cost for execution works on TS and maintenance of buses in all enterprises for the public transport network. In scientific basis for continued research on more complex problems, large networks of public transport companies in the conditions of Vietnam in the future may be considered based on this mathematical model;

- projected decrease in the number of failures of buses in operation by improving work quality and TS on specialized posts in major enterprises. At the same time, the coefficient of readiness of bus fleet will rise, thus the buses job on the line will not be interrupted, which resulting in satisfaction of the urban population in the transportation and cost reduction (or increase the profit of the enterprises). In addition, the optimization of the redistribution of the flow of repairs between small and major companies considered in this paper, allows you to adjust or to organize various kinds of works on TO and TS rolling stock and capacity of enterprises, both now and in the future;

- While increasing the quality of operation, reducing the number of failures of buses satisfying the needs of the population in the traffic, demand in the purchase of new buses is reduced;

- Reorganization for the types of work and TS in the enterprise network, the change of capacity and re-equipment of enterprises for specialized posts or the creation of new posts only happens in major enterprises. This may be cause additional costs on the network of existing enterprises, but, in principle and in the future, in accordance with the development of the public transport system of the city of Hanoi, economic efficiency should obviously increase.

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