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# Methods of Establishing and Implementing the Optimal Fares for Passenger Transport

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**Abstract:** Issues and problems of organization and management of urban passenger transport systems have always been the main research subject for many scientists. Managing the transportation of passengers is particularly connected with the issues of tariff setting for urban passenger transport routes, improving distribution circuits of transport and related financial flows, determining fare exposure patterns on the performance measure of urban passenger transport systems. Raised and resolved tasks in the scientific work are essential for resolution to the issues related to the organization and management of urban passenger transport systems. The approaches are of particular interest in practical and theoretical parts in the organization and management of urban passenger management systems through fares mechanisms and distribution of transport work.

**Keywords:** Transport, Tariff, System, Transportation, Passengers, Fare

## 1. Introduction

At the present stage of development of urban passenger transport systems one of the most important task is to create economically safe and environmentally friendly public passenger transport systems, focused on the interests of transport companies, market, society. The reformation of the urban passenger transport systems requires not only governmental regulation of the transport companies, but also probacy of the methods and tools for optimizing their organizational activities [1].

The rapid development of society in all facets causes an increase of domestic and industrial needs of the urban population, with the constant increasing of the mobility of the population, which leads to a redistribution of its urban mass passenger transport in private.

One of the mechanisms to curb the increase of urban passenger transport systems are tariff control mechanism on fares in urban passenger transport [2].

The control system provides public passenger transport the main task, i.e. to create some conditions for the urban citizens under which they have chosen the transportation in urban public transport instead of using their own vehicle. Viewed in this way, the theme of the research is relevant [3].

## 2. Analysis of Published Data and Problem Definition

The fare value should provide reimbursement amount for motor transport enterprise, but the process of preparing proposals for setting fares and their approval is also related with the need to take into account the socio-economic interests of citizens [4].

The modern stage of tariff setting for urban passenger transport route is characterized by the inadequate control of the public authorities. This leads to economically unjustified tariffs, which inflate spending on transportation for citizens and deprive the possibility to send these funds to meet other needs, which in turn impedes social and economic development of the citizens.

The calculation of economic value due to the fare for urban transportation can be performed using the formula [5]

$$T = \left[ B(1 + r/100) \right] / Q, \tag{1}$$

where *B*-The value of economical costs for operating the enterprise, resulting from the calculation of business plans, UAH.;

$r$-The average economical rate of gross profit of the carriers, %;

$Q$-Planned volume of passenger transportation, passenger.

According to this method of calculation of the fare, the passenger has to pay for passage of the entire length of the route without taking into account the services, that were actually received.

According to the known patterns, the urban and suburban routes are of the one-way traffic in the morning and in the evening and uniform traffic during the business day. For the most part, each bus route is divided into stops, which are placed according to the requirements, taking into account population density and walking distance for passengers to the stop [6-9]. Distance between stops are accepted as route sites, whose number is from $i$ to $n$. In such a case a tariff is a monetary expression unit cost of the provided services, and the formation of tariff is called the tariff setting [10].

In this scientific work, the object of study is the process of formation of tariffs, collecting fares from the passengers. The purpose of the work is to analyse the existing methods of calculating fares in urban passenger transport of general use and the existing methods of tolling from passengers. In this paper the authors to put the following tasks: to make proposals for the formation of the tariffs and the establishment of appropriate means of fundraising according to the analysis.

## 3. Research Results

Under the existing system of calculating tariffs on city routes of public in Ukraine, the passenger pays the fare without regard to the true service received. But it can be calculated.

Passengers are able to board and deboard only at stops, that are the borders of the site. That is why the received service may be determined by the formula

$$T = \left[ \begin{array}{l} B_{n1}\left(1+r/100\right)Q_{n1} + B_{n2}\left(1+r/100\right)Q_{n2} + \ldots \\ + B_{ni}\left(1+r/100\right)Q_{ni} \end{array} \right] \Big/ \left(Q_{n1} + Q_{n2} + \ldots + Q_{ni}\right) , \quad (2)$$

where $B_n$-is the value of economical costs for operational activities of the company within $n$-th areas, UAH.;

$Q_{ni}$ -The estimated volume of passengers $n$-th areas on $i$-th route, passenger.

This approach in determining tariffs on routes allows more faithful calculating of the cost for the services for passengers, but also it is not perfect on the grounds of permanent changes in the volume of traffic on the route and transportation costs fluctuations (changes in the cost of spare parts, power resources, wages and other impact of the environment on public passenger transport system).

The offer to get the appropriate tariff for transportation cannot force to change the tariff relatively to the part of a day, season, direction of the transportation and other factors that shape the demand on the transportation. That the services of one zone, while moving in forward and reverse, at the same time, can vary in number for several times.

The monitoring the routes proves that in the morning and evening there are the sites of the route without the appropriate demand on them, and the use of the proposed approach for calculating the tariff in such cases can lead to direct losses for the enterprise. In most cases, the passenger throughput is one-sided and predictable for each route, and a passenger uses the same trajectory of moving forward and backward. Consider the case of inclusion of the value of inverse and direct route in the tariff (3.3):

$$T = \frac{\left[2B_{n1}(1+r/100)\left(Q_{n1p}+Q_{n1з}\right)+2B_{n2}(1+r/100)\left(Q_{n2p}+Q_{n2з}\right)+\ldots+2B_{ni}(1+r/100)\left(Q_{nip}+Q_{niз}\right)\right]}{\left[\left(Q_{n1p}+Q_{n1з}\right)+\left(Q_{n2p}+Q_{n2з}\right)+\ldots+\left(Q_{nip}+Q_{niз}\right)\right]}, \quad (3)$$

where $B_{ni}$ -The value of economical costs for operational activities of the enterprise within $n$-the areas on $i$-th route, UAH.;

$Q_{nin}$ − The predicted volume of passenger traffic *n-th* areas in the straight direction *i-th* route, passenger.

$Q_{niз}$ − The predicted volume of passenger traffic *n-th* areas in the opposite direction *i-th* route, passenger.

The calculation of the tariff for the transportation on the site of the route by the formula (3) allows the carrier to make a profit on the executed work and satisfies the needs of passengers, which are transported in the opposite direction, in the average price.

In order to achieve the slightest confusion in tariffs for the same route overnight it is offered not to calculate the different tariffs at different parts of the day and take them as one for each route. The total daily rate according to the above approach can be defined by the formula

$$T = \sum_{n=1}^{N} B_{ni}(1+r/100) \Big/ \sum_{n=1}^{N} Q_{ni}, \quad (4)$$

where $\sum_{i=1}^{n} B_{ni}$ is the value of economical costs for operational activities of the company within *n-th* areas, UAH.

$\sum_{n=1}^{N} Q_{ni}$ the daily average volume of passenger transported $n$-th side of the route in both directions, passenger.

As concerns to the city as a whole

$$T = \sum_{i=1}^{n} B_i (1 + r/100) \Big/ \sum_{i=1}^{n} Q_i, \qquad (5)$$

where $B_i -$ is the annual average costs on $i$th route, UAH.;

$Q_i -$ The annual traffic volume on $i$-th route, passenger.

This synthesis can be carried out with taking into account the seasonal fluctuations in demand on the transportation, but, with the constant changes in transportation costs, it does not have the urgency with the influence of time, which can complicate the calculations of economic projects for carriers. The usage of the approach mentioned above enables the carrier to implement a simplified system of issuing tickets. Along with this, there will be a big difference in profits of the enterprises. This is determined by a significant difference in traffic volumes in forward and backward directions.

It is known [9] that the cost of the transportation of the passengers- $S_{naci}$ can be expressed in terms of transportation costs, namely

$$S_{naci} = \frac{l_{Mi}}{q_{Hi}\gamma_{ci}\beta_i k_{3Mi}} \left( B_{3Mi} + \frac{B_{cmi}}{V_{ei}} \right), \qquad (6)$$

or

$$S_{naci} = \frac{l_{cpi}}{q_{Hi}\gamma_{ci}\beta_i} \left( B_{3Mi} + \frac{B_{cmi}}{V_{ei}} \right), \qquad (7)$$

where $S_{naci} -$ is the cost of transportation and passenger on i-th route, UAH. / passenger.;

-the passenger capacity of the vehicle;

$l_{Mi} -$ the length of $i$--th route, km;

$l_{cpi} -$ the average distance of the passenger transportation on $i$-th route, km;

$\gamma_{ci}$ , $\gamma_{\partial i}$ , $\beta_i -$ the static and dynamic coefficients fill of the cabin of the vehicle on $i$-th route, the mileage on $i$-th route respectively;

$k_{3Mi} -$ turnover ratio for $i$-th route;

$B_{3Mi}$ , $B_{cmi} -$ variable and established costs on $i$-th route respectively, UAH / km, UAH. / hr.;

$V_{ei} -$ the operational speed on $i$-th route, km / h.

Then the dependability (4) is:

$$T = \sum_{i=1}^{n} \left[ \left[ \frac{l_{Mi} Q_i}{q_{Hi}\gamma_{ci}\beta_i k_{3Mi}} \left( B_{3Mi} + \frac{B_{cmi}}{V_{ei}} \right) \right] (1 + r/100) \right] \Big/ \sum_{i=1}^{n} Q_i \; . \qquad (8)$$

The analysis of this dependability suggests that taken for the implementation fare, calculated i the city, cannot arrange all the carriers. This is the city average fare paid for transportation in urban passenger transport and it is also suitable for short routes with high passenger capacity, but for the long routes with low passenger capacity this rate is extremely profitable.

For example, if to take on any route its length for $X_1'$ provisionally, and the operation factor of the passenger capacity for $X_2'$, then regarding to its settlement tariff $T_i$ on the route $M_1$

$$T_{M_1} = \frac{X_1' (1 + r/100)}{q_{M_1} X_2' \beta_{M_1} \eta_{M_1}} \left( B_{3M_{M_1}} + \frac{B_{cm_{M_1}}}{V_{e_{M_1}}} \right), \qquad (9)$$

On the other conventional route where the route length is twice as long $X_1'' = 2X_1'$ , and the operation factor of the passenger capacity is twice smaller $X_2'' = 0,5X_2'$ , $T_{M_2}$ can be calculated by the dependability:

$$T_{M2} = \frac{2X_1' (1 + r/100)}{q_{HM_1} 0,5X_2' \beta_{M_1} k_{3MM_1}} \left( B_{3M_{M_1}} + \frac{B_{cm_{M_1}}}{V_{e_{M_1}}} \right), \qquad (10)$$

under conditions

$q_{HM_1} = q_{HM_2}; \beta_{M_1} = \beta_{M_2}; k_{3MM_1} = k_{3MM_2}; B_{3M_{M_1}} = B_{3M_{M2}};$

$B_{cm_{M_1}} = B_{cm_{M2}}; V_{e_{M_1}} = V_{e_{M2}}.$

If we define the ratio of tariff for the first and second routes through dependence (9) and (10), then

$$\frac{T_{M_1}}{T_{M_2}} = \frac{\dfrac{X_1' (1 + r/100)}{q_{M_1} X_2' \beta_{M_1} \eta_{M_1}} \left( B_{3M_{M_1}} + \dfrac{B_{cm_{M_1}}}{V_{e_{M_1}}} \right)}{\dfrac{2X_1' (1 + r/100)}{q_{M_1} 0,5X_2' \beta_{M_1} \eta_{M_1}} \left( B_{3M_{M_1}} + \dfrac{B_{cm_{M_1}}}{V_{e_{M_1}}} \right)} . \qquad (11)$$

After retrenchments

$$T_{M_1} = 4T_{M_2} . \qquad (12)$$

Namely, the fares for city routes may differ exponentially, and this situation is typical. For example, the first short route, which connects the station and the market, where the maximum cabin capacity is provided in forward and backward directions, and the second long route connects the industrial area from and the commuter area, where the cabin is full for one way, and for the other it is empty.

These ratio calculations of tariffs, when the passenger pays for the transportation on various routes, makes the autonomy of each route and prevent the use of a single ticket. In such a case the setting of the fare depending on the transportation distance will provide the value of profit based on executed work by the transport for the carrier, and the fare for the passengers according to the service received.

It is known, that there are fares for the transportation of passengers, that are calculating not depending on the entire trip, but on its length. There is the fare for the whole transportation, e.g. for kilometre, while the fare for transportation is:

$$T_{njMi} = T_{n.кмi} \cdot l_{nj}, \tag{13}$$

where $T_{njMi}-$ is the cost of the transportation of $j$-th passenger on $i$-th route, UAH.;

$T_{n.кмi}-$ the fare for one passenger transported on $i$-th route for a distance of one kilometre, UAH. / km;

$l_{nj}-$ the length of the transportation of $j$-th passenger.

It is known, that $T_{n.кмi}$ can be expressed in the prime cost per passenger-kilometre on $i$-th route $S_{n.кмi}$ [9]

$$T_{n.кмi} = S_{n.кмi}(1 + r/100), \tag{14}$$

where $(1 + r/100)-$ is the agreed level of profitability.

Then, using the known dependability [10], we get

$$T_{n.кмi} = \frac{1}{q_{нi}\gamma_{\partial i}\beta_i}\left(B_{змi} + \frac{B_{cmi}}{V_{ei}}\right)(1 + r/100). \tag{15}$$

Then $j$-th passenger $M_i$ pays $T_{загjMi}$ funds for the transportation with the length $l_j$ on the route

$$T_{загji} = T_{n.кмi} \cdot l_j, \tag{16}$$

or

$$T_{загji} = \frac{l_j}{q_i\gamma_{\partial i}\beta_i}\left(B_{змi} + \frac{B_{cmi}}{V_{ei}}\right)(1 + r/100). \tag{17}$$

While analyzing the dependability (15) it can be argued that the tariff for transportation on one kilometre is not depended, as fare per the transportation (8) from the length of the transportation and other conditions, depends on the coefficient of dynamic cabin capacity $\gamma_{\partial i}$.

Thus, if we consider the two routes, the route of $\gamma_{\partial 1} \approx 1$ (In forward and backward directions the cabin capacity is maximum), and on the route $\gamma_{\partial 2} \approx 0,5$ (In the forward direction the cabin of the vehicle is completely full, and in the backward it is half empty), the ratio $\frac{T_{n.км1}}{T_{n.км2}}$ looks like

$$\frac{T_{n.км1}}{T_{n.км2}} = \frac{\dfrac{(1 + r/100)}{q_1\gamma_{\partial 1}\beta_{м1}}\left(B_{зм1} + \dfrac{B_{cm1}}{V_{ем1}}\right)}{\dfrac{(1 + r/100)}{q_2\gamma_{\partial 2}\beta_2}\left(B_{зм2} + \dfrac{B_{cm2}}{V_{ем2}}\right)}, \tag{18}$$

at $\beta_1 = \beta_2$; $q_1 = q_2$; $B_{зм1} = B_{зм2}$; $B_{cm1} = B_{cm2}$; $V_{e1} = V_{e2}$ after the cuts we have

$$T_{n.км1} = 2T_{n.км2}. \tag{19}$$

In average in the city $T_{n.кмM}$ the fare per passenger-kilometre can be calculated by the dependability:

$$T_{n.кмM} = \frac{B_M(1 + r/100)}{W_M}, \tag{20}$$

where $B_M-$ is the total expense of carriers for transporting the passengers, UAH.;

$W_M-$ total transport work, passenger-km.

Similarly, (5) dependability (20) has such a form:

$$T = \sum_{i=1}^{n} B_i(1 + r/100) \Bigg/ \sum_{i=1}^{n} W_i, \tag{21}$$

where $W_i-$ is the total transport work for a year on $i$-th route, UAH.

When the system fares in the city depends on the distance of the transportation, the routes are divided into areas (from stop to stop), each of them has its own fare and passenger pays for its entire path of the transportation, as the cost of the areas s/he crosses:

$$T = \sum_{n=1}^{N} T_n, \tag{22}$$

where $T_n$ is a tariff for transportation in the relevant area.

$n$ is the number of tariff areas.

Thus, the considered method allows to use the differentiated fare for passengers, depending on the distance of their transportation. This will provide the carrier the income, depending on executed transport work, and passenger will spend the actual amount, according to the service received.

At this stage of the method of collecting toll fares for transportation in urban passenger routes there are various types of tickets. Paper tickets in the past were replaced by the electromagnetic cards, which provide an opportunity to tempt the Internet and cell phones when paying for transportation in urban passenger transport [11-20].

The practical implementation of electronic cards showed their undoubted advantage over paper tickets, but the development of modern technologies has led to the emergence and, in the result, using of the electronic tickets (e-tickets) in the system of public passenger transport [90-102]. However, this form of tickets to ensure public passenger transport system requires significant investment and highly technological developed system.

The current practice of the fare includes the following areas [21, 22, 5, 11-22]

1) Payment for transportation in the cabin.

2) The fare depending on the distance of the transportation.

3) The fare with the help of the single ticket.

Each of these areas has its own scheme of financial flows.

Scheme of financial disposition in the system of public passenger transport with the application of fixed and differentiated tariffs is shown in Figure 1.

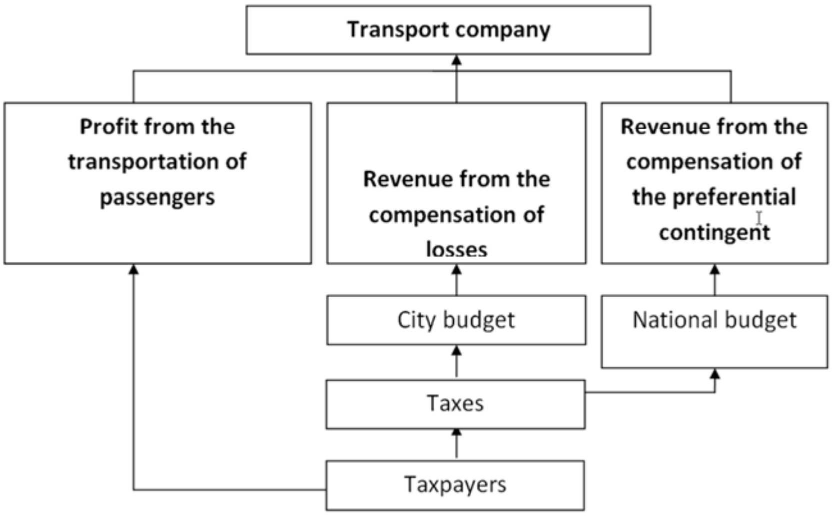


***Figure 1.*** *The scheme of financial disposition in the system of public passenger transport with the application of fixed and differentiated tariffs.*

With the implementation of the schemes of financial flows (Figure 2) total costs $B_M$ on the organization of passenger traffic, based on (8) can be calculated by a formula based on the volume of transportations in the city:

$$B_M = \sum_{i=1}^{n} \left[ \frac{l_{\textit{м}i} Q_i}{q_{\textit{н}i} \gamma_{ci} \beta_i k_{\textit{зм}i}} \left( B_{\textit{зм}i} + \frac{B_{cmi}}{V_{ei}} \right) \right]. \qquad (23)$$

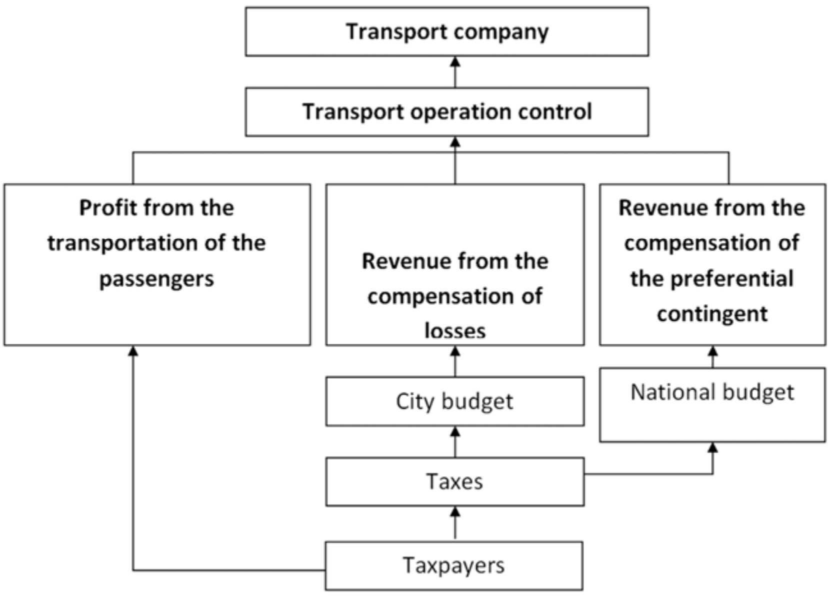


***Figure 2.*** *The scheme of financial disposition in the system of public passenger transport with the application of the "entire ticket."*

Similarly, based on the traffic of the city and dependability (15) the total costs $B_M$ for the organization of passenger transportation can be calculated as

$$B_M = \sum_{i=1}^{n}\left[\frac{W_i}{q_i\gamma_{\partial i}\beta_i}\left(B_{\text{зм}i} + \frac{B_{cmi}}{V_{ei}}\right)\right], \qquad (24)$$

where $W_i$ is the transport work on *i*-th route, passenger·km.

In this case $B_M$ contains the cost of production and sale of the tickets $B_{\text{кв}}$, and does not include the cost of service of the transport to allocate additional pay for it or pay for tickets purchased for the transportation $B_{\text{єкв}}$.

The scheme of financial flows in the system of public passenger transport in the application of "a single ticket" is shown in Figure 2.

In this case, the costs for the organizing of the transportation $B_M$ do not contain costs for selling and purchase of the tickets inside the TF $B_{\text{єкв}}$, but they contain the costs of transport management authority for the implementation of "a single ticket" and sharing common values between the carriers in proportion to the executed work.

Suppose that the structure of operator control has the following type as it is shown in Figure 3.

In accordance with the structure we see, that the bulk of the costs for the organization of controls ($B_{\text{ОРГ.КЕР}}$) consists of:

- expenses on a payroll for the personnel of the department of the work and performance of the operating units control to ensure the introduction of fares;
- maintenance of operating devices;
- devices maintenance cost for recharging of the "single ticket" and so on.

When using "a single ticket", it allows you to travel in any urban passenger transport.

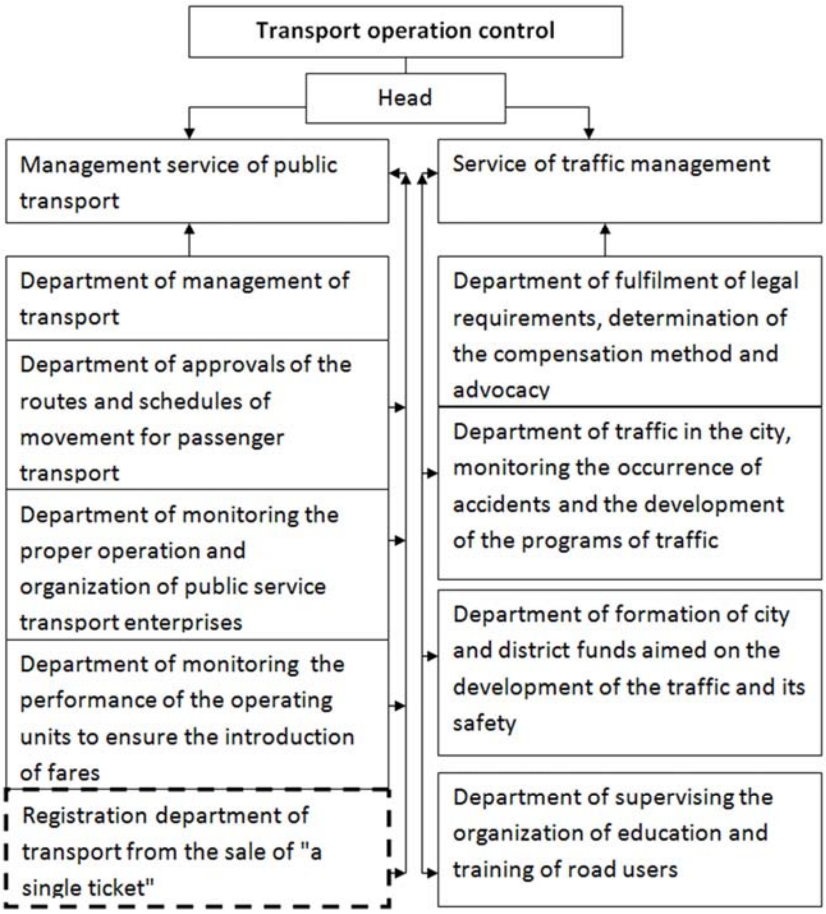


***Figure 3.*** *The structure of transport management.*

Total expenditure on the organization of transportation $B_{MЄ}$ significantly differs from similar costs $B_{MP}$ at different rates on different routes. In the first case:

$$B_{MЄ} = B_{MЄO} + B_{MЄE}, \qquad (25)$$

where $B_{MЄE}$ is the general operating costs for transport companies to perform services;

$B_{MЄO}$ the total expense of local governments in the organization of transport.

In turn

$$B_{MЄO} = B_{MЄO3} + B_{MЄOБ}, \qquad (26)$$

where $B_{MЄO3}$ is the total expense of the traffic control department associated with the performance of traditional common functions;

$B_{MЄОБ}$ -The expense of inspection route of transport and distribution in total revenue.

With it, $B_{MЄE}$ are combined from the operating expenses for work vehicles and related infrastructure $B_{MЄET}$ and the expenses of check takers and jumpers $B_{MЄEK}$ that is

$$B_{MЄE} = B_{MЄET} + B_{MЄEK}. \quad (27)$$

Then

$$B_{MЄ} = B_{MЄO3} + B_{MЄОБ} + B_{MЄET} + B_{MЄEK}. \quad (28)$$

With the implementation of check takers on routes autonomous MPT tickets, general city expenses to carry passengers $B_{MP}$ are consisting of total operating expenses for transport companies to carry out transport $B_{MPE}$ and total expenditures of local governments in the organization of transportations $B_{MPO}$:

$$B_{MP} = B_{MPE} + B_{MPO}. \quad (29)$$

In turn

$$B_{MPO} = B_{MPO3} + B_{MPOБ}, \quad (30)$$

where $B_{MPO3}$ are the total expenses of the traffic control administration on the implementation of traditional common functions;

$B_{MPOБ}$ -The expense of inspection route of transport and distribution in total revenue.

At the same time operating costs $B_{MPE}$ consists of expenses for functioning infrastructure with vehicles $B_{MPET}$ and the cost of controllers $B_{MPEK}$

$$B_{MPE} = B_{MPET} + B_{MPEK}. \quad (31)$$

Then the equation (29) has the form

$$B_{MP} = B_{MPO3} + B_{MPOБ} + B_{MPET} + B_{MPEK}. \quad (32)$$

Based on current practice we can suggest, that

$$B_{MЄET} = B_{MPET}. \quad (33)$$

That means, that the operating costs for transport companies on infrastructure and vehicular traffic is not depended on ticket forms, whether it is "a single ticket" or not. It can be argued that the costs of public transport control administration for performing the traditional functions either do not depend on whether it is a centralized "single ticket" or not:

$$B_{MЄO3} = B_{MPO3}. \quad (34)$$

To solve the question of expediency of "a single ticket" can be used in equations of the following costs

$$B_{MЄ} = B_{MP}. \quad (35)$$

Or on the basis of equations (28) and (32)

$$B_{MЄO3} + B_{MЄОБ} + B_{MЄET} + B_{MЄEK} = B_{MPO3} + B_{MPOБ} + B_{MPET} + B_{MPEK}, \quad (36)$$

Considering (33), (34) the equation is

$$B_{MЄОБ} + B_{MЄEK} = B_{MPOБ} + B_{MPEK}. \quad (37)$$

There is no doubt that there are no costs for distribution and collection of total revenues in the distribution of tickets by every enterprise

$$B_{MPOБ} = 0. \quad (38)$$

Also there are no expenses for the check takers in the "single tickets"

$$B_{MЄEK} = 0. \quad (39)$$

Then the equation (37) takes the form

$$B_{MЄОБ} = B_{MPEK}. \quad (40)$$

The equation written above (40) describes the ratio of the share of costs when working with the check takers (right side) and in the "single ticket" (left side), i.e. if

$$B_{MЄОБ} \leq B_{MPEK}, \quad (41)$$

preference is in the traditional way of collecting revenue via check takers, and, conversely, if

$$B_{MЄОБ} > B_{MPEK}, \quad (42)$$

the advantage is the introduction of "a single ticket".

The data mentioned above shows that when the costs for the organizing of a special unit on the introduction of "single ticket" are less than the total cost of the carriers to distribute tickets via check takers, the use of "a single ticket" is appropriate. In such a way the financial flow in the organization of urban passenger transport (Figure 2, Figure 3) the evidence of independence financing of the governing body of the "single ticket" because in all cases the primary source is the taxpayer.

## 4. Discussion of the Results of Research and Provide Tariff-Setting Tolls

The authors note that the improvement of the methods of public passenger transport has to focus on the priority of urban passenger transport. At the same time, the questions the role of local budgets in relation to rational proportion of social, economic and budgetary components in the total costs for urban passenger transport is not settled enough. Such systems of organizing the interaction control components which would satisfy motivation of carriers and passengers, as well, require the additional development.

The using of the proposed provisions makes it possible to develop a system of charging which takes into account the economic interests of the carrier obtaining the necessary revenue and would ensure the largest passenger fare, depending on the services actually received.

The practical significance of the results is that the approaches to the organization and management of urban passenger transport systems through the management and distribution tariff mechanisms of transport are proposed. The proposed scientific approaches can be used by municipal authorities and transport companies in solving of the tasks with the organization and management of urban passenger transport.

## 5. Conclusion

The approach to tariff setting allows the development of a system of charging, which takes into account the economic needs of the carrier obtaining the necessary profit and ensure passenger the size of payment for moving to MPAs based on actually received services.

The distribution of financial flows in the system of public passenger transport in the application of fixed and differentiated tariffs is analysed. The tools to assess the feasibility of introducing a charge for travel with a passenger in certain circumstances are established.

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