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EXPENDITURE MODEL OF LINE RANKING IN THE PUBLIC MASS PASSENGERS TRANSPORTATION SYSTEM

ABSTRACT

In all the cities of Serbia that have organized systems of public mass passenger transport (PMPT), over the past several years more and more private transport companies are being included in the network of city and suburban transportation lines. The inclusion of private transport companies in the PMPT system via public tenders should be preceded by the procedure of calculation of the realistic income and system functioning expenses in order to establish possible balances of needs for City Budget subsidies, as well as the elements on Contract of entrusting this vital communal activity of every city. The new principle for determining the total cost of PMPT system functioning, based on line difficulty ranking, has been presented in this paper.

KEY WORDS

expenditure model, price, PMPT system, line, exploitation parameters, evaluation, line rank

1. INTRODUCTION

The role of public mass passenger transportation (PMPT) in the cities need not be proved nowadays, as it has been generally accepted that it represents a vital function in the lives of all the citizens, economy and activities in the city.

However, it is a bigger problem how to make this system function better and more efficiently, and create the conditions for raising the transport service quality to a much higher level, making it closer to EU and the developed world city trends.

Key trends in this activity are:

– commitment and care of local communities to provide mobility of citizens and PMPT, with limited use of passenger cars, according to sustainable development and quality of life strategies;
– opening of services market to all the transport companies and all types of ownership;
– need to increase production efficiency and decrease costs of transport companies, and
– pressure of the citizens on the local authorities to implement higher quality level with a more appropriate price of services in PMPT, and unique ticket for all the transport companies and types of transport.

During the 1990s dramatic changes happened in almost all the cities and towns with organized PMPT systems: a lot of people moved into towns/cities, economic stability of population decreased, there were changes in legal and political areas of work and living that influenced an increase in PMPT system usage.

On the other hand, PMPT systems were not able to keep up with these abrupt changes and maintain the existing development trend when it came to resources, application of contemporary methods, techniques and technologies in organization and management. All that resulted in bad functioning and decrease of transportation services quality as well as almost dramatic deterioration of economic and financial activities of almost all transport companies.

New systems of public mass passenger transport (PMPT) in cities are becoming increasingly complex in both structure (more transport companies, more subsystems) and functioning (the need to integrate all the transport companies into system in functional, tariff and logical sense) and, as consequence, in organization and management.

The role of local authorities in this process is of key importance as it means the pressure upon transport companies that are usually inert when it comes to change, as well as creation of a stable, long-term system to be developed in controlled conditions. One of the most important tasks of local authorities is to establish system expenditures for the wanted service quality level.

According to contemporary trends as well as needs of citizens, the PMPT system in our cities should be completely restructured and redesigned in order to change the existing non-satisfactory state into a satisfactory one – public passenger transportation of a higher quality with more acceptable prices for both passengers and transport companies and with lower use of cars.

Therefore, the basic aim of this paper is the presentation of possible procedure for determining the realistic total cost of PMPT system functioning in such manner that the expenditure is established in the function of different conditions of vehicle exploitation by lines or their rank (line rank).

2. WORLDWIDE EXPERIENCES IN THIS AREA

The city transport system with its performances (efficiency, capacity, speed), technology (visual subsystems), quality, expenditures (investment and exploitation) and influence on the environment represents one of the most important factors influencing the location, size and structure of cities, their economy, social relations, etc.

Ever since 1970s there have been ideas to increase financial support to PMPT. This was especially pointed out in two reports of CEMT/ECMT[1], out of which one was related to the coordination of PMPT (CM/71/23 of November 1971), and the other related to PMPT financing (CM/72/13 of December 1972).

Nowadays there are discussions on what makes the quality of living in the cities and what makes a city agreeable to live in. According to UN and OECO documents, the following elements are important for that: home, neighbourhood, safety, economic possibilities, health, mobility, recreation [1].

There are two basic strategies in the development of the cities – "sustainable development" and "quality of living". Sustainable development means that the development of the cities should be according to economic, social and other possibilities. On the other hand, the structure and functioning of the cities should provide the so-called user-friendly environment.

Sustainable development is unimaginable without the development of infrastructure, application of scientific activities related to planning and promotion related to life in general as well as the economic activities [2].

As far as transport is concerned, the quality of living enables the mobility of population along with car usage control [3].

In the EU, achieving sustainable development and the quality of living related to transportation systems is done through policies based on the principle of mobility realization with limited car use [4].

Changes that are important for PMPT system that took place in the EU countries refer to:

– increase in the population number in the cities and the surrounding areas;
– expansion of the cities into the areas with lower density of population that cannot provide minimal transport demands, that could enable economically efficient PMPT systems;
– higher dispersion of travelling in space and time with, at the same time, lower intensity of transport demands [5].

According to the abovementioned there have been changes in demands and political objectives related to PMPT systems.

Having in mind the world globalization processes, changes in political, social and industrial environments in which cities in Serbia and their transport systems function nowadays, it seems necessary to develop new models and methods of management related to cities and their transport systems. The new concept and development strategy of PMPT system has created the need to include private transportation companies, so that through transformation of these systems in the Serbian cities the situation would change from unwanted to a desired one, according to world trends and local possibilities, in accordance with generally accepted strategy of sustainable development and the quality of living.

In 1993, Prof. dr. R. Brankovic pointed out in his work that in defining of the future policies of the PMPT system in the Serbian cities one has to start from the already defined significance of this system and its social interest, from the need to increase passengers mobility and to improve the visual distribution of PMPT, as well as to minimise the losses in this system, and all that in order to provide the best conditions for travelling of citizens within a city [6].

In his work, Prof. dr. R. Brankovic states that the basic problem that appears in the Serbian cities with organized PMPT systems is the lack of continuity in understanding the traffic problems, and that it is done occasionally. There is also a large number of institutions that take part in decision-making related to problem solving of the PMPT system promotion [7].

In the paper by Prof. dr. P. Gladović with a group of authors, a concept of a new policy in the area of PMPT is suggested and two groups of questions are discussed:

– financing of the ongoing PMPT Enterprise activities, and
– financing of the PMPT system development.

The following topics are defined in the paper:

– Principles for transport process projecting on PMPT system network,
– Principles for establishing of the price of ongoing activities (cost),
– Principles for establishing of transport service quality,
– Principles for defining of program Contract between the transport company and City management,
– Principles for policies of transportation cost,
– Principles for establishing of the needed income,
– Principles for including the privately owned transport companies into PMPT lines [8].

More detailed explanations of certain principles have been presented by Prof. dr. P. Gladović et al. at the 1st Conference with international participation – "Modern tendencies of improving traffic in cities". This paper particularly defined the way in which the relation between expenses and income in the PMPT system is established, done according to a unique methodology in the Serbian cities [9].

3. ESTABLISHING RATIO OF INCOME AND EXPENSES IN PMPT SYSTEM

Based on the experience of the developed cities in the world, UITP recommendation and cities in our country recommendation (from cities in which multiple

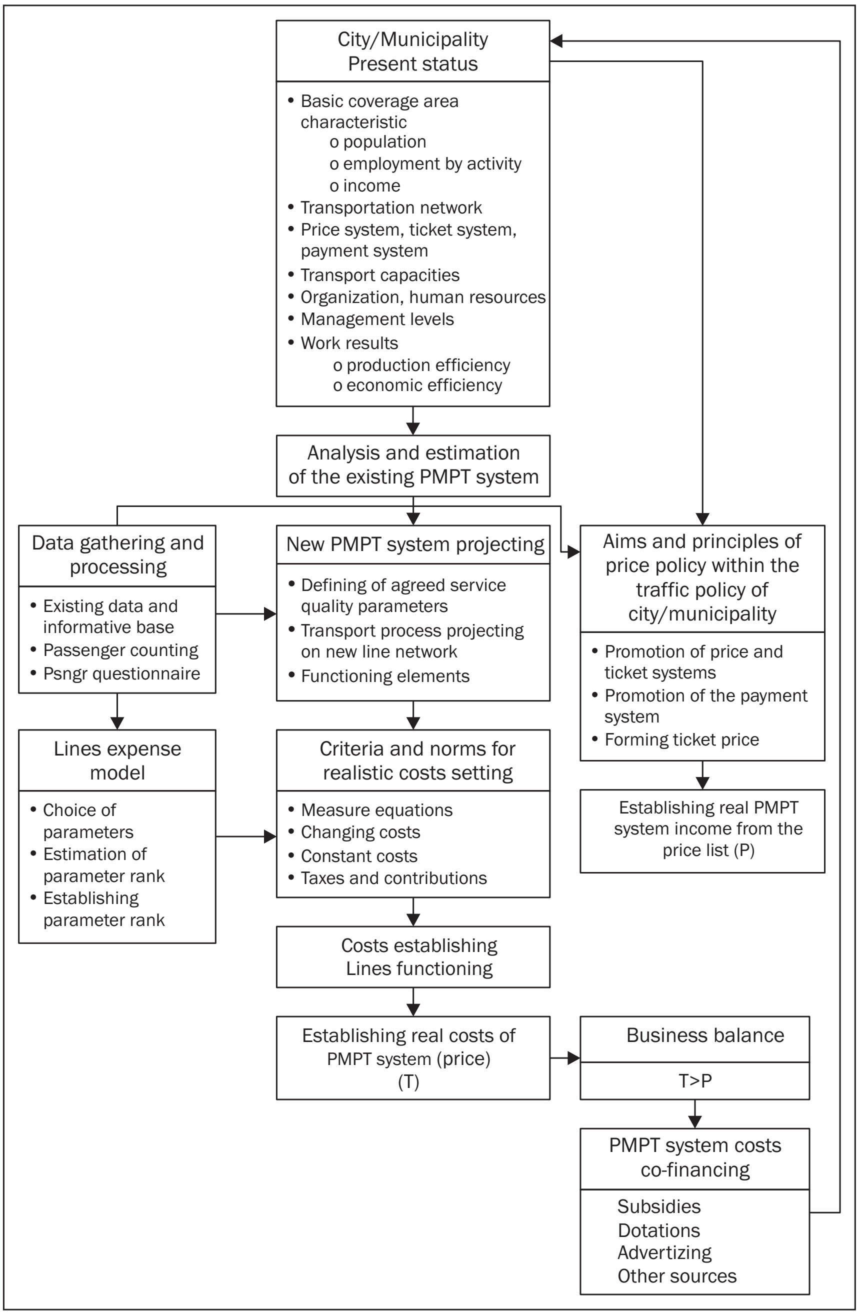

Figure 1 - Scheme of determining the income and expenses in PMPT system

transport companies are operating), this paper offers a new concept of establishing realistic income and expenditures in PMPT system, as presented in *Figure 1*.

As seen in *Figure 1*, the projections of transport process, on optimal PMPT line network, are implemented based on the established relevant transport demands and other necessary parameters (counting and passenger questionnaires), as well as arranged quality of transport service. Based on the range and quality of transport service within the projected transport process, the realistic system functioning expenditures could be obtained, but only with previously established conditions of vehicle exploitation by lines (line rank), i.e. the previously set criteria and norms for these expenditure identification. As no gain is calculated in the PMPT financing, the necessary gain should cover the realistic system functioning costs, and it consists of proceeds from transport service payments, subsidies, subventions and other profits like advertisements, etc.

4. LINE RANK AND CATEGORIZATION

Line rank needs to be performed in order to establish realistic expenses of vehicle exploitation on each line and in total, at system level. The value of entry parameters for expenditure calculations directly depends on the intensity and terms of vehicle exploitation, and is different for each line.

In this model, the defined demand for objective estimation of the line rank consists of (*Figure 1*):

- choice and way of quantifying the exploitation parameters,
- parameter values normalization,
- line rank parameters valuation, and
- lines categorization.

Based on the line rank determined in this way, and in its function, norms or realistic expenditures of each line and the total for all the lines in the system – price of the PMPT system could be identified.

4.1 Setting of exploitation parameters

For each sub-system (bus, tram, trolley, trains) separately, the influencing parameters have been divided into three groups:

- parameters of line trace,
- parameters of passenger flows on the line, and
- parameters related to bus stops and terminals.

Line traces parameters consist of:

1. Length of line in km,
2. Number of crossroads per line km,
3. Number of traffic lights per line km,
4. Total length of yellow lines per km of line (bus, trolley),
5. Number of 90 degrees angle turns per line km,
6. Trace position related to city area – *TR*,

$$TR = \frac{\sum_1^4 Pi \times li}{L}, \quad (1)$$

where:

- Pi – rank of zone line passing through,
- li – length of a part of the line trace within one zone (km),
- L – line length (km);

7. Number of traffic lights on the slope (>5%) per kilometre of line,
8. Separation of line trace - *Ir*

$$Ir = \frac{\sum_1^l li}{2L}, \quad (2)$$

where:

- $\sum li$ – length of independent part of the road of the remaining traffic in both ways per kilometre,
- $2L$ – total length of lines in both directions (km).

9. Number of turns, crosses, sections per kilometre of line (for trams and trolley).

Parameters of passenger flow consist of:

10. Passenger exchange coefficient,
11. Number of passengers/places per flow.

Parameters of stops and terminals consist of:

12. Number of stops per line km,
13. Number of stops on the slopes (>5%),
14. Number of separate stops per line km,
15. Traffic functionality of terminals - *St*.

Evaluation of this parameter is done depending on:

- separation of terminals from the rest of traffic (t_1),
- frequency of vehicles on the terminal (t_2),
- total number of lines on the terminal (t_3),
- signal-lighting equipment on the terminal (t_4).

$$St = \frac{\sum_1^4 ti}{4}, \quad (3)$$

where:

- ti – stands for individual point values of each of the influencing elements for each separate terminal.

4.1 Normalization of the parameter values

Normalization of parameter values is done in the function of the final estimation of line rank in points, giving the line rank in points, giving the line rank value $V * Sij$ as belonging to i parameter class ($i = 1, 2, \ldots, g$), j line ($j = 1, 2, \ldots, m$), where the width of ΔSni class parameter subsystem is defined by the formula:

$$\Delta Sni = \frac{Kni\max - Kni\min}{m}, i = 1, r, \quad (4)$$

where:

- n – the total number of subsystem lines, *Kni* – i subsystem parameter,

r – total number of parameters of subsystem (without the number of stops per line km parameters),

m – defined number of subsystem classes.

Since the direction of the parameters influence on the total estimation of line rank in points is different, the normalization of parameter values is done according to the following:

- parameters number 2, 3, 5, 6, 7, 9, 10, 11, 12 and 13 are valued by classes from 1 to *m*, according to increasing line of parameter classes,
- parameters number 1, 4, 8, 14 and 15 are valued by classes from 1 to *m*, opposite to increasing line of parameter classes.

4.2 Evaluation of the parameter rank

Evaluation of the parameter rank is done by a multi-regressive analysis, by establishing the partial correlative dependences of each of the influencing parameters in relation to the exploitation subsystem speed (as an etalon for evaluating of all the parameters influencing the line rank), i.e.:

$$Wi = \frac{Kpri}{\sum_i^r Kpri} \times 100(\%), \sum_i^r Wi = 100(\%), \qquad (5)$$

where:

Wi – calculated % of the i parameter of subsystem participation,

Kpri – coefficient of partial regression of i parameter and exploitation subsystem speed.

NOTE: Based on formula (5), the preliminary surveys on PMPT lines network in Belgrade indicate that parameter 12 (number of bus-stops per line kilometre) is especially important for line rank regarding tram and bus lines (12.70% on bus lines and 12.84% on tram lines), whereas within trolley sub-system this parameter is insignificant, as in Belgrade PMPT all the trolley lines intersect at the same stops, or they do not differ significantly in the total number of stops.

4.3 Establishing the line rank

The rank of the line is established based on the line rank *Ktj* coefficient value in points as:

$$Ktj = \sum_i^r B \times Sij \times Wi, \; j = 1, n, \qquad (6)$$

where:

*B * Sij* – value of the belonging class of *i* parameter in points,

j – *j* subsystem line,

Wi – calculated % of line rank participation of parameter,

n – total number of subsystem lines.

4.5 Line categorization

Line categorization is based on the level of lines by subsystems given in advance - *N* (recommendation *N* = 3 - 6), where the width of the level range *GT*, is determined as:

$$GT = \frac{KTs\max - KTs\min}{N}, \qquad (7)$$

where:

Ktsmax – maximal value of subsystem line rank coefficient (in theory *Ktsmax* = *m*, *m*-given number of parameter classes),

Ktsmin – minimal value of subsystem line rank coefficient (in theory *Ktsmin* = 1).

5. SETTING THE REALISTIC COSTS ON THE LINES AND TOTAL SYSTEM EXPENSES

The establishing of the system expenses is an important segment in the PMPT system financing, in order to determine the exact subsidies amounts, i.e. lacking funds. In order to determine the expenses of the system, the expenditure model for line ranking needs to be made (as presented in *Figure 1*), consisting of the following costs:

- *Salary expenses* - this type of costs is established for all the vehicles needed for the implementation of projected timetable. The number of employees per one vehicle needs to be defined in the total costs calculation.
- *Vehicle amortisation expenses.*
- *Amortisation of vehicle parking and maintenance space.*
- *Other expenses* - consisting of: vehicle parking buildings maintenance, property insurance, taxes, communal services, office supplies and other minor expenses.
- *Regular vehicle services after certain mileage as recommended by producers.*
- *Regular vehicle maintenance.*
- *Fuel expenses.*
- *Vehicle and passengers insurance and registration expenses.*
- *Pneumatics use expenses.*

Based on the presented expenses and defined norms for their values, the calculation of realistic expenses for one vehicle (solo and double) can be performed, by kilometre in function of line rank (or the established line category – point 4.5), as presented in *Figure 1*. It is important to note that norms for use of fuel, spare parts and tyres need to be set for each line category, as their values depend on line ranks.

It is possible to determine the total expenses of vehicle use per line and in total - at the system level, through information on line length, planned number of included vehicles and number of turns per timetable for each line and calculated unit prices (din/km) by types of vehicles within line ranking.

The system price, established by this expenditure model of line rank, relates only to current operations, i.e. costs related to the implementation of timetable (investment and system development expenses not included).

If the calculated expense is higher than the income, there is the need and the obligation of the local government to provide the necessary funding out of other sources (City of Municipality Budget subsidies) to cover the cost of PMPT system functioning [10].

6. CONCLUSUION

During the past several years, the transport market has significantly changed in the Serbian towns with an organized PMPT system, so the concept of regulated market model (according to which only one transport company – public enterprise is performing this activity) is less and less used. The model of limited competitors is becoming more popular. The new concept of PMPT system organization means the inclusion of a larger number of private transport companies into the system, so that the service quality in such a system depends on the service quality of all the companies. Financing and projected service quality control represent a special issue.

The original line ranking model of public mass passenger transport (PMPT) in cities, based on which the exploitation expenses of vehicles per line and in total, at the system level are determined was presented in this paper. With complex organisational and technological systems, such as PMPT, where the terms of vehicle exploitation per various line are very different, there is an objective demand to establish expenses as realistic as possible. The vehicle exploitation costs per line are part of Transport Contract, signed by the Transport Company and the City. The application of this model creates conditions for a long-term quality of service at a required level, as the Companies are stimulated to operate based on the realistic expenses set for each line individually, in the function of line ranking.

Since this model is based on respecting the specific defined number and types of relevant parameters, with regards to specific intensity and direction of those parameters influence, the method gains a universal character and is applicable in any PMPT system.

However, the model suggests permanent monitoring of changes in the chosen relevant parameters at all the PMPT lines, especially the ones with a significant influence of line ranking upon the expenses in the system. Therefore, the applicability of the above-mentioned model depends on the way of tracking, noting and updating of necessary changes of elements directly defining the influence or parameter criteria.

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SAŽETAK

TROŠKOVNI MODEL ZA TEŽINSKO RANGIRANJE LINIJA U JAVNOM MASOVNOM TRANSPORTU PUTNIKA

Poslednjih godina u svim većim gradovima Srbije, koji imaju organizovan sistem javnog masovnog transporta putnika (JMTP), dolazi do uključivanja sve vise privatnih prevoznika na mreži gradskih i prigradskih linija. Uključivanju privatnih prevoznika u sistem JMTP-a putem javnog konkursa, treba da prethodi prethodni postupak proračuna realnog prihoda i troškova mnkcionisanja sistema, kako bi se utvrdili mogući bilansi potreba za subvencijama i dotacijama iz Budžeta grada, kao i elementi Ugovora o poveravanju obavljanja ove vitalne komunalne delatnosti svakog Grada. U radu će biti prezentiran novi princip određivanja ukupnih troškova funkcionisanja sistema JMTP, na osnovu težinskog rangiranja linija.

KLJUČNE REČI

Troškovni model, cena koštanja, sistem JMTP-a, linija, eksploatacioni parametri, vrednovanje, težinski rang linije.

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