ECONOMIC ASPECTS OF SELECTING MEANS OF BUS TRANSPORT

Maciej Woropay, Daniel Perczyński

University of Technology and Life Sciences, Machine Maintenance Department
S. Kaliskiego Street 7, 85-791 Bydgoszcz, Poland
tel.: +48 52 3408495, +48 52 3408297, fax:+48 52 3408495
e-mail: kem@utp.edu.pl, perkol@utp.edu.pl

Abstract

The paper presents a method of selecting technical objects for performance of the tasks received by the controlling subsystem. The investigation object, being the basis to illustrate considerations presented herein, is an operation and maintenance system of an urban bus transport in a selected agglomeration. Transportation of passengers by means of bus transport is performed in the determined quantitative and territorial scope (specified by a schedule of transport task performance). When operating and maintaining buses various events occur, the results of which have an influence on the processes of using and servicing the buses, as well as on their technical condition and economic effect of the work of the system in which they are used. The buses of an urban transport system, during the operation and maintenance process, may be in various maintenance states forming the state space S. It is important, in the aspect of assuring continuity of performance of transport tasks and the technical and economic efficiency achieved by the system, that as many vehicles as possible are in the state of serviceability and perform the transport tasks during the phase of a working cycle. It is affected by such factors as: the features of the vehicles being operated and maintained, the type of the equipment and number of the service sites of the service station and of the units of technical emergency service, providing the units of technical emergency service with diagnostic apparatuses, the nature of the transport tasks being performed, the method and scope of performance of the service processes and others. So, there is a possibility to have an influence on the system economic efficiency by selecting the buses with the use of the economic criterion.

Keywords: *transport, bus transport, maintenance process, economic criterion, road transport*

1. Introduction

The buses operated and maintained in an urban transport system of Poland constitute a mixture of various makes and types. Also, an extensive sales offer of manufacturers in the sector of urban buses is observed in the market. Because the maintenance process is defined as a sum of the processes concerning the machines in their maintenance phase, being crucial for efficiency of their use or possibilities of achievement of partial goals, an important problem is a correct selection of a bus for performance of transport tasks.

Rapid development of urban agglomerations has been observed in Poland for more than ten years. An increase in the people's migration, growing number of residents, increased mobility of the society make that the city borders is continuously extended. Therefore, we deal with the following phenomena in the urban transport:

- increase in the number of passengers,
- elongation of an average trip distance,
- increase in the number of buses in an urban transport system.

All those factors determine looking for more and more effective solutions in scope of selecting technical objects to be operated and maintained in the specific system. The elements supporting a decision maker in the process of making decisions concerning the control of the process of selection (purchase) of a bus of the specific make (type) to be operated and maintained may be the results of the investigations of economic models and computer programs to simulate changes of this process. Because alternative buses of an urban transport system are supposed to perform the same transport tasks, the paper does not consider technical aspects of the analysed technical objects.

2. Investigation object

The investigation object is a maintenance system of buses in an urban transport system in a selected agglomeration.

Transport of passengers by means of a bus transport system is performed in a specific quantitative and territorial scope (determined by the schedule of performance of transport tasks).

Various events occur during maintenance of buses, the effects of which have an influence on the processes of using and servicing buses, as well as on their technical condition and economic effect of the work of the system in which they are used. The buses of an urban transport system may be in different maintenance states in the maintenance process.

A bus transport system performs tasks in consecutive maintenance phases forming a duty cycle (Fig. 1). The following maintenance phases creating a duty cycle have been distinguished: f_1 – element activation phase, f_2 – task performance phase, f_3 – servicing phase (after completing daily transport tasks), f_4 – phase of waiting for inclusion in the use process (so called organizational standstill).

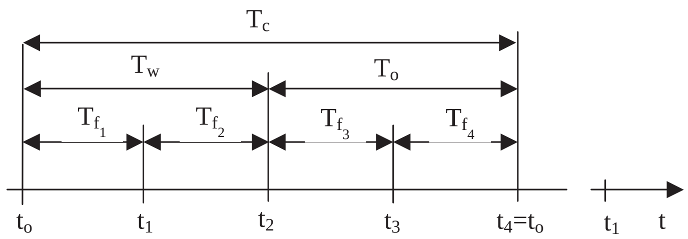

Fig. 1. Duty cycle. T_w – time, when a technical objects stays in an executive subsystem (process subsystem), T_o – time, when a technical objects stays in a servicing subsystem (of a service station or a hard standing), T_c – duration of one cycle

In the task performance phase f_1 the particular elementary subsystems of the <H-TO> (driver-bus) type perform the transport tasks they were entrusted with. Due to a possibility of occurrence of damage to a bus or a driver's unfitness state the time of performance of the transport tasks by the particular elementary subsystems is random. In the investigated maintenance system a damaged bus is directed to the serviceability assurance subsystem, where it is subject to the renewal processes (servicing processes).

After completing the servicing processes a serviceable vehicle is directed to perform tasks or so called hard standing (if directly after completed servicing the vehicle cannot undertake a task due to the schedule of transport tasks implemented in the system).

In order to restore, as quickly as possible, serviceability of the vehicles, which got damaged when performing the tasks, so called units of technical emergency service are used. The scope of services (repairs) performed by the operators of the technical emergency service is limited by the existing technical equipment of those units and the necessity to perform services outside the service station site.

The vehicle whose serviceability state has been restored due to the actions of the operators of the units of technical emergency service is directed to perform a transport task (it undertakes interrupted performance of the task).

It is important, in the aspect of assuring continuity of performance of the transport tasks as well as technical and economic efficiency achieved by the system, that as large number of vehicles as possible is in the serviceability state and perform transport tasks during the phase f_1 of the duty cycle. It is influenced by such factors as: features of the operated and maintained vehicles, type of equipment and number of the service stands of the service station and units of technical emergency service, provision of the units of technical emergency service with diagnostic tools, nature of the transport tasks being performed, method and scope of performance of the servicing processes and others.

Therefore, it is possible to influence the economic result of the system resulting from performance of the transport tasks undertaken.

In light of the foregoing the further part of the paper will present the method of developing an economic model, the study of which will make it possible to evaluate influence of the selected decision variants on efficiency of the analysed process.

3. Method of economic evaluation of the investments

The investments in a transport system are capital intensive investments utilised for a relatively long period of time. Therefore, there is a significant time span between the moment of spending investment expenditures on purchase of a bus and the moments at which cash related to their maintenance is spent and incomes related to the performance of the transport tasks are obtained. Consequently, in the economic analyses, it is necessary to include a time factor, taking into account a change of the money value in time by applying economic criteria, in which streams of costs are used in the adopted investment utilisation period and assumed percentage rate. The stream of costs K related to the maintenance of a mean of bus transport may be described by the general relation as follows:

$$K = \sum_{t=1}^{n} K_t \cdot (1+p)^{-t}, \tag{1}$$

where:

K_t - cost in the year t,

p - percentage rate,

t - next years of investment utilisation,

n - number of years of economic analysis.

The generally applied method to evaluate investment profitability is the net present value (*NPV*) method described by the following relation:

$$NPV = \sum_{t=1}^{n} CF_t \cdot (1+p)^{-t} - K_A, \tag{2}$$

where:

NPV - net present value,

CF_t - cash flows during the period t,

K_A - initial expenditures related to the purchase of a mean of transport.

The *NPV* method belongs to the category of dynamic methods and it is based on the analysis of discounted cash flows with the determined percentage rate. The net present value, obtained by using this method, illustrates a difference between the streams of total incomes generated by implementation of the new investment and total expenditures for purchase of a bus and its maintenance.

In the investment profitability analysis which must be performed in order to guarantee safe and punctual passenger transports, various variants of performance of the investment fulfilling the same tasks are considered. Therefore, the incomes for the transport service will be the same in the considered variants. Hence, in order to select an optimal solution based on the NPV method, further considerations include only a sum of the values of the investment and maintenance costs, omitting the incomes for the service performed.

4. Cost characteristics

The total investment cost related to the purchase of a bus may be presented by the relation:

$$K_A = K_z + K_d \,, \tag{3}$$

where:
K_z - cost of purchase of a bus,
K_d - additional costs related to implementation of the investment.

If a bus make which was not operated and maintained before in the system is considered in the analysed variant of the economic evaluation of the investment efficiency, then additional costs should be added to the investment cost. The following components should be included among the additional costs:

- cost of providing the service stands of the service station and units of technical emergency service with extra diagnostic equipment and tools assuring correct performance of the servicing processes of a mean of transport of the analysed variant,
- cost of training of the service staff and drivers,
- cost of implementation of a ticket system and a transport management system,
- cost of adaptation of the bus colours and indispensable graphic information (identification number, etc.).

In general, the expenses related to the purchase or production of fixed assets are not included among the tax deductible expenses at the moment they are spent, but gradually when being used by capital allowance. However, only the components of assets constituting fixed assets or intangible assets according to the statutory definitions are subject to these requirements. The bus amortisation cost may be presented by the following relation:

$$K_{am} = K_z \cdot r_{am} \,, \tag{4}$$

where:
K_{am} - bus amortisation cost,
r_{am} - amortisation cost coefficient resulting from the act on the list of annual amortisation rates.

A bus just like other motor vehicles is subject to obligatory vehicle insurance. Because of the fact that many companies operate in the insurance market, and prices of the insurance services offered by them differ as to their value, this component of the costs is omitted in the further analysis. Moreover, a business entity being the owner of the operated and maintained technical object may also use an additional insurance (Assistance, Auto Casco). Consequently, this component of costs would assume a similar value and would not influence the result of the analysis in the considered variants.

The costs related to the maintenance of a mean of urban transport should include the monetary value of flue gas emission calculated according to the appendix to the legislative resolution of the European Parliament of 22 October 2008 on revised proposal concerning the directive of the European Parliament and of the Council on the promotion of clean and energy efficient road transport vehicles (COM (2007) 0817 - C6-0008/2008 - 2005/0283(COD)). Because the buses, analysed in particular variants, are supposed to perform the same transport tasks, it means that they are to be characterised by equal technical parameters, this component of the costs is omitted in further considerations.

An important component of the costs resulting from maintenance of a bus is expenses related to the service, repair and maintenance of a mean of transport K_s. This cost is presented by the following relation:

$$K_s = K_{oc} + K_{ot} + K_{na} + K_{os} + K_{nk} + K_{nks} \,, \tag{5}$$

where:
K_{oc} - cost of daily service,
K_{ot} - cost of technical service,
K_{na} - cost of repairs performed in the service station and by the units of technical emergency service,
K_{os} - personal costs (remunerations and remuneration related costs),

K_{nk} - cost of repairs of ticket punchers,
K_{nks} - cost of repair and maintenance of communication system (radiotelephone).

The most important component of the costs, presented by the relation (6), resulting from bus maintenance are costs related to the provision of a technical object with propellants, oils, lubricants and functional fluids, etc. (K_{pos}).

$$K_{pos} = K_{mp} + K_{ol} + K_{sip} + K_{og}, \tag{6}$$

where:
K_{mp} - cost of propellants (fuel),
K_{ol} - cost of engine and transmission oil,
K_{sip} - cost of lubricants and functional fluids,
K_{og} - cost of tyres.

5. Model of economic evaluation of the investment efficiency

To develop a model of economic evaluation of the investment efficiency related to the purchase of a new bus, the net present value (NPV) method was applied. The form of the criterion functional is presented by the following relation:

$$F_i = \sum_{t=1}^{n} K_{am_i} \cdot (1+p)^{-t} + \sum_{t=1}^{n} K_{s_i} \cdot (1+p)^{-t} + \sum_{t=1}^{n} K_{pos_i} \cdot (1+p)^{-t} + K_{A_i}, \tag{7}$$

where:
i - i-th computational variant.

When performing analysis of the obtained values of the criterion functional for the particular buses of urban transport, the optimal variant will be the one, for which the value of the functional F_i will be the smallest, it means:

$$F_{opt} = \min(F_i), \tag{8}$$

where:
F_i - value of the functional for the i-th variant.

6. Selected results of the maintenance study

The study covered one of the urban transport enterprises operating within the area of central-northern Poland from 01.01.2010 to 31.03.2010. The aforementioned enterprise operates and maintains more than 150 buses in its system. The average age of the operated and maintained buses is 8.125 years. The selected results of the performed investigations are presented in the Tab. 1. and 2.

The Table 2. shows a collective specification of the costs related to maintenance of the means of an urban bus transport system including the unit costs expressed in PLN/bus-kilometre.

In the first quarter of 2010 the buses made in total more than 3254000 bus-kilometres. While, the unit cost was 5.40 PLN/bus-kilometre, and the total costs resulting from maintenance of the buses amounted to 17561835 PLN.

The analysis of the costs gives an idea about management efficiency in all the links of a business entity and about its work as a whole unit. The purpose of the analysis of the costs is to provide information on the factors affecting their level, dynamics and structure. It allows revealing and locating possibilities, which were not used before, and methods of using them, in order to achieve the highest possible level of profit from the business activity. The analysis of the structure of the costs allows learning more about the internal composition of the costs and it is usually based on the percentage relation of the particular elements of the costs to the total costs. The Tab. 3. shows the structure of the costs in the analysed enterprise.

Tab. 1. Specification of the buses operated and maintained in the analysed enterprise

Item	Bus make and type	Number of units	Production year
1	Mercedes Benz Conecto LF G	3	2009
2	Mercedes Benz Conecto LF	3	2008
3	Mercedes Citaro G 2008	12	2008
4	Mercedes Citaro G 2007	9	2007
5	Mercedes Citaro	2	2007
6	Mercedes Conecto G	10	2005
7	Mercedes Conecto G	13	2006
8	Mercedes Conecto G	9	2007
9	Volvo 7000A	4	2001
10	Volvo B10 BLE	31	1997
11	Volvo B10 BLE	4	1998
12	Volvo B10 BLE	6	2001
13	Volvo B10 BLE6x2	3	1999
14	Volvo B10 BLE6x2	8	2000
15	Volvo B10 LA	13	1998
16	Volvo B10 LA	2	1999
17	Volvo B10 L	7	1998
18	Volvo B10 MA	9	1997
19	Volvo B10 MA	6	1998
20	MAN NG313	5	2000
21	MAN NG313	2	2001
22	MAN NG313	2	2002
23	MAN NL 223	7	2000
24	Jelcz M181M/1	8	1999
	Total	178	

Tab. 2. Collective specification of the costs rel ated to maintenance of buses of an urban transport system in the analysed urban transport enterprise

Cost specification	1st quarter of 2010	
	Cost	Unit cost
	PLN	PLN/bus-kilometre
Propellants	5337600	1.6403
Tyres	160860	0.0494
Other materials	126000	0.0387
Amortisation	2957000	0.9087
Daily service	238830	0.0733
Technical service	198512	0.0610
Personal costs and costs related to them	5834183	1.7930
Cost of repairs	2671350	0.8210
Cost of repairs of ticket punchers	27500	0.0084

Cost of repair and maintenance of communication system	10000	0.0031

Tab. 3. Structure of the costs in the analysed enterprise of urban bus transport

Cost specification	Share in the total costs
	%
Propellants	30.39
Tyres	0.92
Other materials	0.72
Amortisation	16.84
Daily service	1.36
Technical service	1.13
Personal costs and costs related to them	33.22
Cost of repairs	15.21
Cost of repairs of ticket punchers	0.16
Cost of repair and maintenance of communication system	0.06

7. Summary

The purpose of the paper was to prepare a development method and to develop a model of selection of buses of an urban transport system to be operated and maintained in the specific system on the basis of an economic criterion. The characteristic feature of the considered model of selection of buses of an urban transport system is its significant simplification. However, the presented method to develop the model of this type and to analyse it show a possibility to use it for preliminary economic evaluation.

The analysis of the obtained results of the study concerning the structure of the costs in the analysed system of an urban bus transport system proves that the largest share in the total maintenance costs belongs to the personal costs and costs related to them (33.22%), costs of propellants (30.39%), amortisation costs (16.84%) as well as the costs related to the processes of restoring technical serviceability (15.21%). Due to the above facts special attention should be paid to correct estimation of their values.

The method, presented in the paper, of selecting buses due to the assumed level of generality of the description may be used to analyse the maintenance process performed in other maintenance system than an urban bus transport system.

It is needed to conduct further study intended to estimate correctly values of the costs related to the maintenance of buses of specific makes and types.

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