ECONOMIC ASPECTS OF A CITY TRANSPORT MEANS PURCHASE

Bogdan LANDOWSKI[1], Daniel PERCZYŃSKI[2], Łukasz MUŚLEWSKI[3], Piotr KOLBER[4]

[1,2,3,4]*Faculty of Mechanical Engineering, University of Science and Technology*

Abstract
The research object is a technical system of city bus transport in a given agglomeration. The study deals with economic aspects involved in a purchasing a transport means. The subject of the study covers issues connected with decision making with incomplete information available. Constant striving for achieving high quality of transport services makes it important to match the transport means with the transport service it provides. The study includes basic assumptions of the method to be used for selection of a vehicle that would be suitable to perform transport services of a public transport system on the basis of economic criteria. The discussed implementation way of an economic method for investment assessment makes it possible to use it for technical systems other than the city transport systems.

Key words: *transport, city transport , maintenance costs, economic criteria.*

INTRODUCTION

In order to improve transport efficiency it is necessary to choose transport means that would effectively perform transport services.
Passenger transport is a very important branch of a city transport system. The notion of city transport, as compared to other forms of transport (automotive, railway, inland water, marine, air transport), was identified by means of horizontal classification, where the classification criterion is differentiation of territorial units, for which transport services are performed. The issue connected with passenger transport in a city has been identified not only according to its territorial operation range but first of all to its functional - economic specificity conditioned by the character of passenger transport services and the way they are provided. Therefore, the notion of passenger transport in a city is often narrowed and identified with the notion of city transport - regular transports of passengers by public transport means over assigned routes (*Landowski, Woropay & Neubauer, 2004; Woropay, Knopik & Landowski, 2001*).
The operation range of city transport is wider than one would expect, basing on its name, as it also covers suburban areas whose functions are similar to those of particular town districts. It needs to be noted that they are often situated at a significant distance from the administrative borders of the city (recreation areas, large industrial plants, etc.) (*Woropay, et al., 2001*).
Rapid development of urban agglomerations has been reported in Poland for the last several years. An increase in population migration, growing number of residents, increased mobility of the society have resulted in continuous extension of town borders. Thus, the city transport is characterized by the following factors:

- increase in the number of passengers,
- prolongation of the average journey distance,
- increase in the number of vehicles in the system of public transport.

Also the market offer of transport means used in public transport systems is observed to have become richer.
All these factors largely affect the search of more effective methods for selection of technical objects to be used in a given technical system.
The results of the economic model tests and computer programs for simulation of a vehicle operation and maintenance process can be used to support transport executives to make decisions about the selection of transport means to perform assigned transport services, under given operation and maintenance conditions and environmental factors. An example of the transport means operation model and other auxiliary tools for decision makers have been discussed in works such as (*Landowski, et al., 2004; Landowski, Perczyński, Kolber & Muślewski, 2016*; *Woropay, et al., 2001*).

MATERIALS AND METHODS

The research object is a real system of city bus transport in an urban agglomeration of app. 400 thousand inhabitants. This system is one of the basic subsystems of the whole city public transport system.

The research was carried out in one of city bus transport systems operating on the territory of mid-northen Poland.

The primary goal of a city bus transport operation is safe carrying of a given number of passengers over an assigned area. However, due to financial limitations, it is necessary to increase economic efficiency of the transport services, thus minimizing the outlays for public city transport.

Maintaining operability of the transport means is the responsibility of the system which ensures operability of vehicles and which cooperates with the diagnostic subsystem.

Damage to an technical object is a random event. During operation of buses there occur different events whose consequences affect the processes of bus operation and maintenance as well as the technical state and economic effect of the transport system. Vehicles used in the process of operation can enter different operational states. The costs of bus repairs and those connected with removal of damage effects as well as other costs involved in maintenance operability of the vehicles are of random character.

The research included the following buses:

- Mercedes-Benz O530 Citaro: 2 psc.,
- Mercedes-Benz O530G Citaro: 21 psc.,
- Mercedes-Benz O345 Conecto LF: 9 psc.,
- Mercedes-Benz O345G Conecto LF: 21 psc.,
- Mercedes-Benz O345G Conecto: 17 psc.,
- Solaris Urbino 12: 14 psc.,
- Solaris Urbino 18: 25 psc.,
- Solaris Urbino 8,6: 2 psc.,
- Mercedes Benz 628 B01 Conecto: 10 psc.,
- Mercedes Benz 628 B02 Conecto G: 1 psc..

A measure of a transport system performance in the analyzed bus transport system is the so called vehicle kilometer meaning coverage of one kilometer of a route by a bus with a definite number of seats (one-body, articulated) during operation. This measure of transport system performance is used in accountancy and tenders for providing city transport services.

The average number of kilometers covered by the buses used in the investigated company was above 13 million kilometers annually.

The most important categories of bus operation costs were determined on the basis of carried out investigations and the structure of costs in the analyzed company of city bus transport. Rational implementation of the bus operation processes involves respective costs including:

- propellants (29.42 % of total costs),
- tires (0.96 %),
- amortization (17.04 %),
- the so called current servicing (1.39 %),
- technical service (1,13 %),
- human related costs and their derivatives (36.22 %),
- repairs (13.21 %),
- installation, servicing and repairs, the so called ticket system (0.14 %),
- installation repairs and maintenance of the transport system 0.08 %),
- remaining (0.41 %).

Since alternative buses of public transport are supposed to perform the same transport tasks this work does not include technical aspects of the analyzed technical objects.

Investments in a transport system are capital consuming though being used in a relatively long time. Thus, there is a significant time span between the moment of a bus purchase and the time of expenses for its operation and maintenance and incomes from provided transport services In connection with this, the economic analyses need to include the time factor. This enables taking into account the change of money value in time. Hence, the used economic criteria take advantage of cost streams

during the accepted operation time for the assumed percentage rate. Further, in this work all the investment outlays, costs and incomes are given in PLN.
Stream of costs K z connected with operation of a city bus transport means can be expressed by the following dependence (*Drury, 2002; Samuelson & Nordhaus, 2012*):

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

where:
K_t – cost in year t, (or another accepted time interval t, e.g. quarter, month, etc.),
p – discount rate (capitalization ratio with reference to the accepted time interval),
t- successive years of the investment operation, (successive analyzed time intervals)
k – number of years for which an economic analysis is to be performed).
Commonly used method for assessment of an investment profitability is the method of net present value NPV described by the following dependence (*Drury, 2002; Samuelson & Nordhaus, 2012*):

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

where:
NPV – net present value,
CF_t – cash flows net (Cash Flow) in period t (cash flow net expected in time t) not including investment outlays,
K_A – initial outlays connected with a purchase of a transport means.
n – number of years of income from an investment.
NPV method is based on an analysis of discounted cash flows with a given percentage rate. Net current value obtained using this method, represents the difference between flows of total incomes from implementation of this method, shows the difference between flows of total incomes from implementation of a new investment, and total outlays for a purchase of a bus and its operation.
In order to An analysis of the investment should include profitability which needs to be performed in order to guarantee safe and timely passenger transports includes different variants of implementation for an investment performing the same function. An investment should be understood as a purchase and next use of a given bus type and make. In the tested object the incomes from performance of transport services in the aspect of transport means operation type are dependent mainly on the number of a vehicle parts and subsequently with the number of seats. The operated are one part vehicles and two part ones , that is articulated.
Thus the incomes for transport services will be considered according to investment variants, for a given type of vehicle (one or two par vehicle), the same. Hence, in order to choose an optimal solution based on a modified method NPV, further only the sum of investment and operation cost values are taken into consideration with negligence of incomes for the performed transport service or other incomes connected with operating a vehicle of a given type.

RESULTS AND DISCUSSION

The categories and characteristics of bus operation costs to be presented in further part of this study result from the method of their recording in the research object. In this way particular kinds of costs can be linked with the vehicle. Acceptance of such a description method enables utilization of real data from the research object for analyses of bus makes and types used in the analyzed system. For vehicles of other makes and types, an estimation of the model parameter values should be made. A method of computer simulation of the transport means operation process, can among others, be used for this purpose.
The Tab. 1 shows a collective specification of the costs (referred to the first quarter of 2016) related to maintenance of buses of an urban transport system in the analysed urban transport enterprise

Tab. 1 Collective specification of the costs

Cost specification	Cost PLN
Propellants	5837733
Tyres	175932
Other materials	137806
Amortisation	3234071
Daily service	261208
Technical service	217112
Cost of repairs	2921655
Cost of repairs of ticket punchers	30076
Cost of repair and maintenance of communication system	10937
Personal costs and costs related to them	6380845

The total cost of the investment connected with a purchase of a bus can be expressed by the following dependence:

$$K_{IN} = K_z + K_d , \tag{3}$$

where:
K_z – bus purchase cost ,
K_d – additional costs connected with introduction of the investment.

If the analyzed variant of the investment economic efficiency assessment applies to an investment into a bus of make and type that has not yet been used in the system, additional costs should include the following components (Woropay & Perczyński, 2010):

- costs of providing service stations of a garage and technical emergency units with new diagnostic equipment and tools for servicing and repair of the analyzed variant,
- costs of service staff and drivers training,
- costs of introduction of a ticket system and transport management system,
- costs of bus color adjustment and necessary graphic information (identification number etc.).

Expenses involved in a purchase or creation of fixed assets are not considered to be tax deductible expenses at the moment they are borne but gradually throughout the period of their being used by depreciation deduction. However, only the estate components considered by law to be fixed assets or intangible and legal assets are subject to this rigor. The cost of bus amortization can be expressed by the following dependence:

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

where:
K_{AM} –annual cost of bus amortization,
r_{am} – amortization cost ratio according to the law regulating annual amortization ratio.

Like other automotive vehicles, buses need to have motor insurance. Due to the fact that there are many insurance companies on the market and the prices of offered services are different, further analysis does not include this component of costs. Moreover, an economic entity owning a technical object can use an additional insurance (assistance, comprehensive cover). In consequence, this cost component would assume a similar value for all considered variants and would not affect the analysis result (Woropay & Perczyński, 2010).

Similarly, the analysis does not include indirect costs such as: department costs, company costs, management costs, etc. These cost components would not affect results of the analysis in the considered variants of the investment.

The costs connected with transport means operation and maintenance should involve a financial value of exhaust fumes emission, calculated according to the annex to legislation resolution of the European Parliament regarding promotion of ecological, clean and energy efficient vehicles in road transport. Since the buses analyzed in particular variants are supposed to perform the same transport tasks, that is, exhibit the same technical parameters, this component will be omitted in further analysis.

Outlays connected with ensuring operability, repair and maintenance of transport means, referred to as K_{OB}, make up an important component of the costs. The cost is expressed by the following dependence:

$$K_{OB} = K_{oc} + K_{ot} + K_{na} + K_{nk} + K_{ns}, \tag{5}$$

where:
K_{oc} - daily service costs,
K_{ot} - technical service costs,
K_{na}- costs of repairs performed in the service station and by technical emergency units,
K_{nk} - costs of bus cash machine repairs,
K_{ns} - repair and maintenance costs of the transport system.
Costs of operating materials K_{ME} are an important component of operation and maintenance costs. The most important ones can be expressed as follows (6).

$$K_{ME} = K_{mp} + K_{ol} + K_{sp} + K_{og}, \tag{6}$$

where:
K_{mp} - cost of propellants (fuel),
K_{ol} - cost of engine and gear box lubricant,
K_{sp} - cost of lubricants and operating fluids,
K_{og} - cost of tires.
It was assumed that human related costs including wages and other related expenses connected with accomplishment of transport services do not depend on the type of transport means and they do not affect the investment evaluation.
To build a model for economic evaluation of efficiency of investment connected with a purchase of a bus, a new modified net present value method (NPV) was used. The form of a criteria based functional is presented by dependence (7).

$$F_i = \sum_{t=1}^{n} K_{OBi} \cdot (1+p)^{-t} + \sum_{t=1}^{n} K_{MEi} \cdot (1+p)^{-t} + K_{INi} - \sum_{t=1}^{a} K_{AM_i} \cdot (1+p)^{-t}, \tag{7}$$

where:
i – i-th calculation variant,
a – number of bus amortization years.
Inclusion of amortization costs in the criteria based functional is connected with their influence on the tax costs involved in operation of the analyzed city bus transport company.
Having analyzed the value of criteria based functional for particular city transport buses it can be said that particular investment variants can be evaluated in the economic aspect I terms of the accepted assumptions. An optimal variant is a variant for which the value of functional F_i is the lowest, that is:

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

where:
F_i - value of the functional for the i-th investment variant.
Presentation of source data sets and calculation variants is not a goal of this study.

CONCLUSIONS

The aim of this study is to present the substance and main assumptions of the developed method for selection of city transport buses to be used in a given company, according to the economic criterion. The considered model for selection of city transport buses is significantly simplified. However, the presented construction method of this type of model and its analyses make it possible to use it for an initial economic assessment of particular investment variants.
In this work only economic criteria for selection of a technical object to be used in a given transport system have been discussed, including technical and safety aspects of transport means. The proposed method should be used for selection of a technical object to perform efficiently transport services in a given transport system.
In practical applications there occurs a problem connected with estimation of values of the model parameters, especially for vehicles of other makes and types than those so far used. Also computer

simulation methods of the transport means operation and maintenance process can be used for estimation of values of the model parameters.
The presented way of description of the economic method for investment assessment allows to use it for technical systems other than a city transport system.
There is a need to conduct further research in order to evaluate properly the values of costs connected with operation and maintenance of buses of given types and makes.

REFERENCES

1. Drury, C. (2002). *Management and Cost Accounting*. Warszawa: PWN.
2. Samuelson, P., A., & Nordhaus, W., D. (2012). *Economy*. Poznań: REBIS.
3. Landowski, B., Perczyński, D., Kolber, P., & Muślewski, Ł. (2016). An example of Markov model of technical objects maintenance process. *Engineering Mechanics 2016, 22nd International Conference* (pp.346-349). Book of full texts: Institute of Thermomechanics Academy of Sciences of the Czech Republic.
4. Landowski, B., Woropay, M., & Neubauer, A. (2004). *Controlling reliability in the transport systems (Sterowanie niezawodnością w systemach transportowych)*. Library of Maintenance Problems. Bydgoszcz-Radom: Maintenance Technology Institute.
5. Woropay, M., Knopik L., & Landowski, B. (2001). *Modeling processes of operation in transport system (Modelowanie procesów eksploatacji w systemie transportowym)*. Library of Maintenance Problems. Bydgoszcz-Radom: Maintenance Technology Institute.
6. Woropay, M., & Perczyński, D. (2010). Economic aspects of selecting means of bus transport. *Journal of KONES*, *17*, 513-519.

Corresponding author:
Ing. Bogdan Landowski, Ph.D., Faculty of Mechanical Engineering, University of Science and Technology, Prof. S. Kaliskiego 7, 85-789 Bydgoszcz, Poland, phone: +48 523408208, e-mail: lbogdan@utp.edu.pl