

## THE ASSESSMENT OF THE EFFECTIVENESS OF MEANS OF TRANSPORT

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### Abstract

As far as the current rules involved in business enterprise operation process are concerned, one of the most significant characteristics is specified by the need of engaging economic criterion in all procedures involved. Thus, it is required to introduce deep and extensive analysis concerning economic aspects of passenger transport. First of all, it is essential to specify currently existing demand for passenger transport service and compare it in relation to the supply capabilities offered by a transport enterprise. Business advantages created by the enterprise are also necessary to be considered and analysed. The basis for transport enterprise operation should be provided with order placed by Passenger Transport Executive, subcontracting firm of a chosen line according to valid schedule including both, rush and after-rush hours. In order to avoid any possible difficulties it is very important that the hired company is informed about all factors influencing economic efficiency of the serviced bus line. As a result, subcontractor is enabled to make right decisions and eliminate potential problems.

Important processes having a considerable influence on proper functioning and effectiveness of public means of transport are connected with its usage, diagnosing and making it fitness for use. Operation effectiveness aspects that are the most frequently discussed in professional literature is described as relations existing between the profits and the input. It takes form of difference or quotient of the values mentioned above.

This paper presents evaluation and analysis method controlling different means of transport operation system effectiveness. Method developed with the aim of analysing and evaluating public means of transport operation effectiveness, provides managerial staff with feedback, which is helpful as far as taking right decisions, is concerned. Making proper choices has a great influence on the process and it bears the responsibility for functioning of the system in terms of reliability and cost efficacy. Certainly, the more professional service is, the more satisfied customers are. Moreover, customer demands are more likely to be met, which means that all involved procedures related with functioning of the system are carried out in the accordance with regulations and requirements, being currently in force.

**Keywords:** transport system, reliability, efficiency

### 1. Introduction

Transport has a large influence on effective functioning of each sector of economy and enhances its development. Apart from performing services to these branches of economy which deal with goods production, transport also provides services for non-production sectors such as: health service, education, administration, system of justice, trade and others. It also provides services for the society satisfying needs of individual customers.

On the basis of an analysis of literature, it is possible to distinguish the following functions performed by transport:

- production function,
- consumption function,
- integration function,
- others.

The demand for transport can be defined as a need or necessity to cover distances, which is fulfilled by carrying people, products, energy and information.

Municipal transport networks whose main goal is to carry out regular passenger transports over a given distance, with the use of common transport means, play a special role in meeting the transport demands.

Within the whole structure of a transportation system, it is road transport which deserves special attention, including both individual and the public one. It is so because of an increasing number of different transport means (especially in private transport).

Compared to individual road transport, the public one has numerous advantages, including the possibility of carrying a bigger number of people simultaneously, which contributes to reduction of traffic intensity, noise and exhaust fumes emission. A special case of a common transport is a municipal one covering also suburban areas which though lying outside the city borders perform functions analogue to those of the city itself. The great role of the municipal transport is reflected by the relation of its efficient and reliable operation with the quality of social and economic life in urban areas. It is needless to say that the most popular kind of public transport is bus transportation. Its main task is to meet the transport demands according to passengers' expectations. Municipal bus transport does not require rails or tracks as other transport means such as trams or electric buses. It is characterized by:

- the widest application range
- spacious character of work
- ability to adjust to the time of transport needs,
- high transport speed.

Despite many advantages of a municipal bus transport system it also poses different hazards to human health and life as well as the environment. Therefore, providing high level of the transport reliability, efficiency and safety is of great importance for its users.

Nowadays, each economic activity must take into account the economic criterion. Thus, it is necessary to carry out reliable analyses of passenger transports. Above all, it is necessary to relate transport demands closely with the supply possibilities and economic results connected with the transport company functioning.

The transport company operation should be based on the line operation ordered by the local government during rush and after-rush hours. In order to facilitate making right decisions it is indispensable to specify properly all factors that affect economic efficiency of bus lines and the rules according to which they are to be specified.

Processes which are of greatest importance for transport means appropriate and efficient functioning are: operating, providing serviceability and diagnosing. Notions of operation efficiency most frequently used in literature [1-5] define it as the relation between benefits (treated as profit in terms of economy) and expenses. It takes the form of a result or quotient of these quantities.

Analyses and efficiency assessment of the municipal transport means functioning will make it possible to make rational decisions by decision makers of the transport system in order to provide it with efficient operation and reduction of costs connected with its functioning. It will enable an improvement in its capability of meeting transport demands that is, functioning according to set requirements.

## **2. Goal**

The research goal is to analyze and evaluate efficiency of transport means used in a bus transport company of a big city complex.

## **3. Identification of the research object**

The research object is a real system of municipal bus transport in a big city complex. The main task of this system is to carry out passenger transports on the territory of the city and in the suburbs. The basic requirements set for this type of systems include:

- providing safety of passenger transports,
- accomplishment of transports along assigned router,
- accomplishment of transports according to a fixed schedule (punctuality and frequency).

In the analyzed system of municipal bus transport there were used 180 transport means (city buses) of different makes and types.

#### 4. Operating tests

Experimental tests were carried out in a real municipal transport system with the use of a passive experiment. Observation of operation of buses took place in conditions normal for their operation, that is, with passenger transports according to the established schedule. 180 buses of different makes and types used in the first and second quarter of 2010 were tested. Operating data on the costs and profits generated by the Municipal Bus Transport Company during the analyzed periods of time was obtained from its source documents.

#### 5. Methodology of the analysis and estimation of effectiveness operate of transport means

On the basis of literature [1-7] there was made a choice of efficiency indexes for technical objects. In order to make an assessment of transport means operation efficiency there was specified a set of chosen values. For the research purpose only such indexes were chosen which are connected with transport means operating and maintenance because these processes generate most costs incurred by the transport company in order to provide the vehicles with serviceability.

To make an assessment of transport means operation efficiency in the examined system, the process model containing a set of technical and economic criteria must be earlier developed.

In effect of the carried out analysis of forms of indexes contained in the developed initial model of efficiency assessment it was observed that some of them do not provide significant information about the examined object. In connection with the above, their number was verified in the assessment model, determining the set of representative indexes which allow making an assessment of the tested transport system efficiency.

The resultant model of transport means operation efficiency assessment in the analyzed system includes the following indexes:

$$W_{Ef} = [W_1, W_2, W_3, W_4, W_5, W_6, W_7]. \quad (1)$$

Determination of values of indexes of the resultant assessment model makes it possible to assess efficiency of the process carried out within the considered system. An analysis of obtained values will enable decision makers to make rational decisions aiming at improvement in operation of the whole system and its subsystems.

The developed model of the process assessment contains the below listed indexes. Their interpretation was proposed as follows:

- index of share of fuel costs ( $W_1$ ) born by the Bus Company:

$$W_1 = \frac{K_1}{\Sigma K}, \quad (2)$$

where:

$K_1$  - cost of fuels,

$\Sigma K$  - total sum of the Bus Transport Company expenses,

- index of share of costs connected with change of tires in the total costs ( $W_2$ ) carried by the Transport Company:

$$W_2 = \frac{K_2}{\Sigma K}, \quad (3)$$

where:

$K_2$  - costs of change of tires of the used vehicles,

$\Sigma K$  - total costs carried by the Transport Company,

- index of share of materials purchase costs in the total costs ( $W_3$ ) incurred by the Company:

$$W_3 = \frac{K_3}{\Sigma K}, \quad (4)$$

where:

$K_3$  - costs of materials,

$\Sigma K$  - total costs carried by the Transport Company,

- index of current repairs share in the total costs ( $W_4$ ) carried by the Transport Company:

$$W_4 = \frac{K_4}{\Sigma K}, \quad (5)$$

where:

$K_4$  - costs of running repairs of operated vehicles,

$\Sigma K$  - total costs carried by the Transport Company,

- index of the share of daily overhauls of the operated vehicles in the total costs ( $W_5$ ) incurred by the Transport Company:

$$W_5 = \frac{K_5}{\Sigma K}, \quad (6)$$

where:

$K_5$  - costs of daily bus overhauls,

$\Sigma K$  - overhead costs of the Transport Company,

- index of the share of costs connected with daily overhauls of the operated vehicles in the overall costs ( $W_6$ ) carried by the Transport Company:

$$W_6 = \frac{K_6}{\Sigma K}, \quad (7)$$

where:

$K_6$  - costs overhauls of operated vehicles,

$\Sigma K$  - overall costs carried by the Transport Company

- index of the share of costs connected with general overhauls of operated vehicles in the overall costs ( $W_7$ ) incurred by the Transport Company:

$$W_7 = \frac{K_7}{\Sigma K}, \quad (8)$$

where:

$K_7$  - costs of general overhauls of operated vehicles,

$\Sigma K$  - overhead costs of the Transport Company.

## 6. Research results and analysis

In result of performed calculations of values of indexes the resultant assessment model of bus operation, there were obtained mean quarter shares of direct operation costs in overhead costs of the Bus Transport Company.

### 6.1. Operating costs

Costs incurred by the Bus Transport Company connected with running operation in I and II quarters of 2010 year have been presented in Tab. 1. Total costs born in connection with current

Tab. 1. Presentation of running costs in PLN, in I & II quarter of 2010

Running costs	Year 2010	
	I quarter	II quarter
fuel	5 337 661	5 081 054
tires	160 864	135 188
other materials	126 000	105 000
amortization	2 957 035	2 913 712
insurances	436 267	436 267
taxes and payments	48 778	48 779
salaries	4 060 291	4 144 094
employment costs	838 342	855 990
energy for bus washing	40 021	48 021
TOTAL COSTS	14 005 259	13 768 105

vehicle operating in I quarter were 14 005 259 PLN, whereas in the next quarter they dropped to 13 768 105 pln.

The above table shows that the factors which generated the highest costs in both quarters were the same and were connected with fuel as in I quarter they accounted for more than 38%, whereas in II quarter for 36.9% of the overhead running operating costs. Higher spending on fuel were caused by heating the vehicles in the winter (which covered I quarter) and longer time needed to reach optimal temperature of the engine operation. Another factor is connected with salaries for employees, thus, in I quarter it accounted for 28.99%, whereas, in II quarter it was 30.10% of expenses.

Amortization charges also turned out to be high though they did not undergo significant changes over 6 months, accounting for approximately 21% of overhead costs. The remaining expenses such as: tires insurance, energy, bus washing, employment and taxes do not generate high costs as they did not exceed 10% in I and II quarter.

## 6.2. Daily operation

Costs connected with daily operation during first three months was 238 831 PLN, whereas during three successive months it was 227 175 PLN These costs include materials, employees' wages taxes, and other payments. The below table shows particular quantities of different expenses (Tab. 2).

Tab. 2. Costs of daily service in PLN accounting for different expenses of the transport company in I and II quarter of the analyzed year

Daily operation	Year 2010	
	I quarter	II quarter
materials	1 601	1 500
salaries	41 713	42 048
employment taxes	7 921	7 985
other costs	104 596	105 642
departmental costs	83 000	70 000
TOTAL COSTS	238 831	227 175

Costs, classified as others, involve the highest percent of expenses as these are sums equal to 104 596 PLN for I quarter 10 562 PLN and for II quarter. They account for the majority of all costs incurred by the transport company for daily operation. Purchase of materials involved the lowest costs and in I quarter of the analyzed year it was only 1601 PLN and in II quarter 1500 PLN.

### 6.3. Costs of servicing

Servicing costs cover all spending connected with servicing-repair activities (technical control, overhauls, repairs) done by the vehicle user or by specialist service companies. These costs were 198 512 PLN in I quarter whereas in II one they were 175 579 PLN (Tab. 3).

Tab. 3. Costs of servicing in PLN accounting for the transport company different expenses during the first two quarters the analyzed year

Servicing	Year 2010	
	I quarter	II quarter
materials	55 000	37 000
wages	47 210	47 545
employment costs	8 970	9 034
departmental costs	87 332	82 000
other costs	0	0
<b>TOTAL COSTS</b>	<b>198 512</b>	<b>175 579</b>

The structure of cost of servicing includes department costs which account for its significant part (I quarter 87 332 PLN, II quarter 82 000 PLN). It is easy to notice a considerable difference in expenses on materials as in I quarter the Transport Company generated costs equal to 55 000 PLN, whereas, in II quarter they amounted only 37 000 pln. Costs connected with employees' salaries were similar – I quarter 47 210 PLN, II quarter 47 545 pln.

### 6.4. Costs of renovation and repairs

Renovations and repairs are inseparably connected with any kind of economic activity. These expenses include payments for workers, necessary materials, and also department costs. Totally, all kinds of repairs involved 3 705 476 PLN in I quarter and 3 437 167 PLN in II quarter (Tab. 4).

Tab. 4. Costs of bus renovations and repairs in PLN from I and II quarter of the analyzed year

Renovations and repairs	Year 2010	
	I quarter	II quarter
running repair	3 668 148	3 399 994
- materials	1 330 000	1 200 000
- salaries	771 915	777 245
- employment taxes	146 664	147 677
- other costs	50 000	50 000
- department costs	1 369 569	1 225 072
repair of punches	27 509	27 663
- materials	8 920	8 920
- salaries	10 000	10 298
- employment taxes	1 889	1 945
- department costs	6 700	6 500
repair and maintenance of communication equipment	9 819	9 510
- materials	2 430	2 400
- salaries	3 440	3 460
- employment taxes	649	653
- department costs	3 300	3 000
<b>TOTAL COSTS</b>	<b>3 705 476</b>	<b>3 437 167</b>

According to the above presented analyses, most of expenses are connected with running repairs as these are activities which are to liquidate damages occurred in result of the vehicle operation, and they are supposed to prevent from occurrence of potential threats. These costs do not vary considerably each other in the two quarters. Repairs of punches generate a slight amount of costs, being 27 000 PLN. Communication equipment also requires maintenance which involves about 9500 pln.

## 6.5. General presentation of costs

During three months the Transport Company bears costs equal to 20 558 234 PLN whereas in the next quarter, it is 19 952 565 pln. Below, there has been presented a table showing all expenses and their percentage shares in overhead costs incurred by the Transport Company.

Tab. 5. Overhead costs in PLN from I and II quarter of 2010 year

Kinds of costs	I quarter	II quarter	Percentage share	
			I quarter	II quarter
running operation	14 005 259	13 768 105	68.12	69.00
daily operation	238 831	227 175	1.16	1.14
servicing	198 512	175 579	0.97	0.88
renovations and repairs	3 705 476	3 437 170	18.02	17.23
department costs	1 077 794	1 030 114	5.24	5.16
overhead company costs	1 332 362	1 314 42	6.48	6.59
<b>TOTAL COSTS</b>	<b>20 558 234</b>	<b>19 952 565</b>	—	—

On the basis of percentage values of cost shares it can be said that the structure of costs in the two considered quarters is very similar, that is, the same factors generate similar costs, regardless of the time of year.

The most cost consuming is the running operation as in the I quarter it accounts for 68.12% and in II quarter 69% of all costs incurred by the Transport Company. Renovations and repairs also play an important role in the structure of all costs as they account for 18.02% in I quarter and 17.23% in II quarter of the Transport Company expenses. Costs of renovations are indispensable as proper operation of transport means is of key importance for accomplishment of transport tasks (Tab. 5).

Comparison the values of chosen indexes from I and II quarters of 2010 year have been presented in Tab. 6.

## 7. Conclusions

Efficient and rational functioning of municipal transport means is one of the main problems of transport companies. It is caused by decreasing subsidies for passenger transports, continuous transformations of economy and competition on the market of transport.

Accomplishment of efficient passenger transports by municipal transport means involves the necessity of keeping them at the proper level of operational reliability and safety. Each case of vehicle damage limits the possibility of transport tasks accomplishment. It results in an increase in costs incurred by the transport company for removing the damages and providing the vehicles with serviceability.

A considerable increase in total costs of maintenance of a bus transport company in the years 2008-2010 is caused by rising prices of services, fuels and other components indispensable for appropriate functioning of a transport company. An important factor generating higher maintenance costs is the fleet of vehicles where old buses of makes such as, e.g. Jelcz or Ikarus are being replaced by modern ones such as, e.g. Volvo, Mann, Mercedes. Mann buses need specialist service and original spare parts which increases considerably their maintenance costs.

Tab. 6. Comparison the values of chosen indexes from I and II quarters of 2010 year

Kinds of costs	Symbol index	I quarter	II quarter	Percentage share	
				I quarter	II quarter
index of share of fuel costs	$W_1$	5 337 661	5 081 054	0.259636	0.254657
index of share of costs connected with change of tires in the total costs	$W_2$	160 864	135 188	0.007825	0.006775
index of share of materials purchase costs in the total costs	$W_3$	126 000	105 000	0.006129	0.005262
index of current repairs share in the total costs	$W_4$	3 668 148	3 399 994	0.178427	0.170404
index of the share of daily overhauls of the operated vehicles in the total costs	$W_5$	238 831	227 175	0.011617	0.011386
index of the share of costs connected with daily overhauls of the operated vehicles in the overall costs	$W_6$	198 512	175 579	0.009656	0.008800
index of the share of costs connected with general overhauls of operated vehicles in the overall costs	$W_7$	3 705 476	3 437 167	0.180243	0.172267

## References

- [1] Bojarski, W., *Podstawy analizy i inżynierii systemów*, PWN, Warszawa 1984.
- [2] Horecki, S., *Efektywność ekonomiczna eksploatacji pojazdów samochodowych w przedsiębiorstwie transportowym*, WKiŁ, Warszawa 1984.
- [3] Kryński, H., *Rachunek ekonomiczny efektywności i zamierzeń inwestycyjnych*, PWN, Warszawa 1978.
- [4] Nowicka-Skowron, M., *Efektywność systemów logistycznych*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2001.
- [5] Oziemski, S., *Efektywność eksploatacji maszyn: podstawy techniczno-ekonomiczne*, Instytut Technologii Eksploatacji, Radom 1999.
- [6] Sienkiewicz, P., *Teoria efektywności systemów*, Zakł. Nar. im. Ossolińskich, Wrocław 1987.
- [7] Ważyńska-Fioł, K., *Podstawy teorii eksploatacji i niezawodności systemów transportowych*, Wydawnictwo Politechniki Warszawskiej, Warszawa 1993.