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ASPECTS OF DECISION-MAKING IN THE MANAGEMENT OF THE LIFE CYCLE OF VEHICLES IN PUBLIC TRANSPORT

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ABSTRACT
The proposed model pointed out the need of optimal choice of vehicle fleet, to define optimal ways of maintaining and method for determining a vehicle's lifetime, or time write-off in terms of cost of ownership and maintenance of vehicles. This paper presents a procedure of assessing the impact of the applied management methods.
Key words*:* The Life cycle, Passenger Transport, Maintenance, Write-off Vehicles, Ownership of Vehicles, Management, Valorization of method

1. INTRODUCTION
The task of a vehicle fleet in public transport is to move passengers from one place to another. Such a task can be successfully and reliably achieved by the fleet if it has sufficient number of technically correct vehicles with a long life cycle and acceptable maintenance costs. The vehicle in the inventory vehicle fleets causes costs for the owner. These costs can be divided into: 1. the costs of the acquisition (write off) and 2. the maintenance costs of the vehicle.
The first item is the largest component, which is about 40-60% of the total cost, which is the main reason for the wide variation in the price of transport. Vehicle type, maintenance mode, vehicle age and other factors affect the level of vehicle participation. The age structure of the vehicle fleet is an important data for assessing the reliability and the need for the maintenance of the transport system.

2. HYPOTHETICAL ASPECTS OF MODELS
The set goals and selected approaches for solving the problems of managing the life of fleets have determined several basic hypothetical starting points of the model:
1) The costs of the vehicle fleet are in the function of monetary and non-monetary factors which if are optimally managed can assure and improve the return on investment.
2) The optimum costs of transport services in public transport are determined by optimizing vehicle purchases, optimizing vehicle residual value up to the time of replacement, minimizing the level of parts stock.
3) The optimization of the route of public transport lines significantly affects the costs of the transport service.
4) The application of new maintenance technologies contributes to improving the efficiency of the fleet management life cycle.

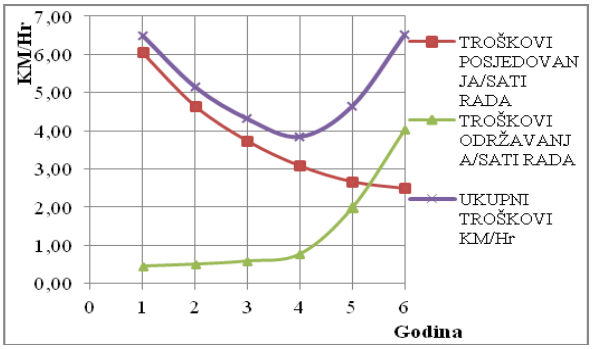
3. VEHICLE LIFE CYCLE MANAGAMENT IN PUBLIC TRANSPORT
Vehicle life cycle management is consisted of three components: Procurement of a vehicle, Exploitation and maintenance, Disposal and replacement.

Vehicle procurement
Knowing the operational processes and requirements of the company, it is necessary, above all to: Analyse real needs (fleet size, vehicle types ...), Analyse the choice of vehicle type and model, Analyse the selection of the appropriate financing, Plan the disposal of vehicles, etc.

Exploitation and maintenance
Establishing a good maintenance plan reduces downtime and increases the value of the vehicle at every point of disposal.
By use of intelligent transport systems are created conditions for the vehicle monitoring during the exploitation at any time, and through a series of sensors connected to board diagnostics it is possible to monitor certain systems on the vehicle (engine temperature, fuel consumption, engine speed, etc.). In this way are created conditions for quality preventive maintenance and corrective maintenance is reduced.

Disposing and replacing vehicles
When making a decision, the following factors should be considered: Financial, Non-financial, Non-qualitative factors (eg company image, employee morale, employee retention, and security).
In today's conditions of the labor market, retaining employees, morale and attracting new employees with newer more comfortable vehicles is not unusual.

3.1 Costs of ownership
When replacing a vehicle, there is often a mistake in thinking that "once purchased property which is totally weakened is not a cost for ownership." In Picture 1. is presented a general example of the relationship between the costs of ownership and maintenance of vehicles of the purchase value of 30000 (KM). From the given graphics it can be concluded that the replacement of the vehicle should be done after 4 years of ownership.



Picture 1. Costs of ownership and maintenance of vehicle type

When purchasing new vehicle its value is determined by these factors: Costs of amortization, Maintenance costs, Fuel costs, Financing, Charges and taxes.

3.2 Exploitation and maintenance costs
Valorization of the effects of applying the model for the selection and maintenance of vehicles in public transport is possible by using the form for calculating the total transport costs, which we calculate as a sum of all costs (fuel, lubricants, tires, repairs and maintenance, depreciation, wages, interest expenses, administration, insurance costs, registration fees and other costs).

$$T_u = \sum T = T_g + T_m + T_{ag} + T_{OP} + T_a + T_{LD} + T_K + T_{UP} + T_{OS} + T_R + T_{ost}$$

Costing is a compilation of spending elements to obtain the cost of goods and services. Costs are calculated from the need to manage the enterprise.

3.3 Total costs of owning and maintaining the vehicle
The costs presented in Table 1. include vehicle ownership and vehicle maintenance costs, based on which the justification of vehicle replacement with correction due to exploitation conditions can be assessed.

Table 1. Owning and maintaining vehicle costs in public transport per unit

Corrected costs per unit		**[KM/km]**
Owning costs		**0,3422**
	Costs of amortization	0,2895
	Ensurance costs	0,0274
	Registrations costs	0,0253
Maintaining costs		**0,6766**
	Tire costs	0,0356
	Costs of maintaince and repair services	0,6410

3.4 An example of vehicle selection

For the Zenicatrans carrier, variants of vehicle purchasing from the aspect of vehicle life cycle were analysed. Two cases of procurement with four variants (offers) were observed. In the first case, it is about new vehicles, and in the second case about used vehicles. The variants are labeled V1, V2, V3 and V4 in both cases.

Table 2. presents the selected metric for the multi-criteria ranking of the offered variants. The weights of the criteria were determined expertly in the range from 1 to 10 and can be adjusted to each specific case.

Table 2. *Criteria for the selection of vehicle in public transport*

Code	**Type of criteria**	**Unit**	**How much the criteria satisfy (MIN ili MAX)**	**Importance of criteria(from 1 to 10)**
001	Number of sitting and standing seats	seats	maksimum	7,00
002	Year of manufacture (can be eliminatory)	year	minimum	8,00
003	Engine power	kW	maksimum	8,00
004	Mileage passed.	km	minimum	7,00
005	Vehicle ownership costs within 1 year after purchase	KM/hr	minimum	9,00
006	Vehicle maintenance costs within 1 year after purchase	KM/hr	minimum	9,00
007	Assessment of vehicle condition		maksimum	8,00
008	Noise	dB	minimum	6,00
009	EURO engine (1,2,3,4,5,6)		maksimum	7,00
010	Vehicle price (KM)	KM	minimum	9,00
011	Transport costs to the carrier (contracting authority)	KM	minimum	9,00
012	Method of payment	month	maksimum	8,00

R.b.	Šifra	Naziv alternative / varijante	Broj bodova
1.	004	Varijanta 4	110,67
2.	003	Varijanta 3	99,57
3.	001	Varijanta 1	97,93
4.	002	Varijanta 2	95,55

R.b.	Šifra	Naziv alternative / varijante	Broj bodova
1.	004	Varijanta 4	112,94
2.	003	Varijanta 3	99,71
3.	001	Varijanta 1	98,78
4.	002	Varijanta 2	95,82

Picture 2.Bid valuation process done by SAW method which uses programme for new and used cars

From the bid valuation process it can be seen that the values of the criteria were approximately the same for each variant from the new one to the used vehicle, so for these reasons the ranking bids are the same. This means that in the vehicle life cycle management, the methodology described can also be applied to used vehicles, with the costs and alteration of their costs different for new and used vehicles, and therefore the life cycle (period of use) is shorter.

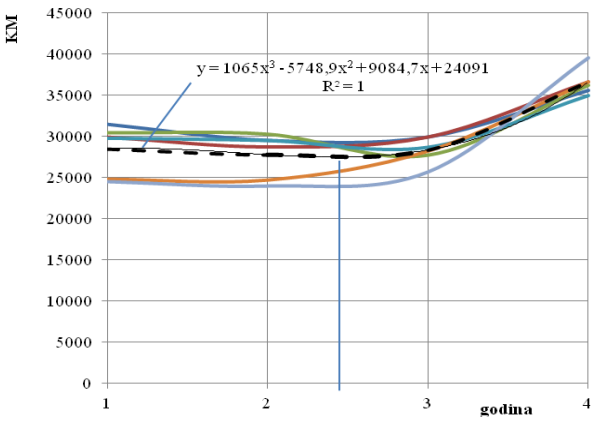
3.5 Optimazing the life cycle of public transport

The optimization of the life cycle of vehicles in the fleet for public transport was carried out on the basis of the costs of owning and maintaining the vehicles, and in accordance with the cost model in point 3.1. For this purpose an analysis of the collected data of the company Zenicatrans Zenica for the

period 2012-2015 was carried out. Ownership costs include amortization, road charges, registration and other fixed costs per vehicle. Maintenance costs include the costs of parts, materials and energy, as well as labor costs.

Since the age structure of the vehicle fleet is very unfavorable, maintenance did not have any continuity in all vehicles. The maintenance of a large number of vehicles was based on the principle of "drive to failure". For the optimization of the life cycle analysis, 6 vehicles have been separated, which were maintained mainly before the failure occurred in the period 2012-2015. The cost of owning the selected vehicles at the beginning of the observed period was approximately 30000 (KM).

The total costs of the selected 6 vehicles can be replaced by the average values and by the method of the smallest squares determine the polynomial approximation function with negligible error, Picture 3.



Picture 3. Owning and maintaining costs for 6 selected vehicles of the vehicle fleet Zenicatrans, 2012-2015

For the specified vehicle group, the optimum replacement time is obtained at the point of minimum of the function y, and depending on the number of years x. This is obtained from the conditions

$$\frac{dy}{dx} = 0$$

$$\frac{d\left(1065x^3 - 5748{,}9x^2 + 9084{,}7x + 24091\right)}{dx} = 0 \quad 3\cdot 1065\cdot x^2 - 2\cdot 5748{,}9\cdot x + 9084{,}7 = 0$$

$$x = 2{,}427 \text{ (year)}.$$

Thus, the 6 vehicles observed, according to the included costs, should have been optimally replaced after the 5th month of 2014.

4. CONCLUSION

Based on the results of the complete survey, it can be concluded that the optimization of the management of the cost of the life cycle of the vehicle fleet significantly improves the conditions for the return of investments in the company for the transport of passengers.

Based on the above, it can be concluded that this research will have the full meaning of applying this model to enable optimal solutions for the maintenance of a fleet in the public transport and can serve as an example of the scientific solution of key problems in the technological process of production of transport services.

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