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## ASSESSMENT OF ECONOMIC LIFE OF FIREFIGHTING AND RESCUE APPLIANCES BASED ON CHASSIS RENAULT MIDLUM IN THE ZLIN REGION

*This paper is focused on the evaluation of economic data obtained from operational records of fire-fighting equipment with a focus on Firefighting and Rescue Appliance type of vehicles, especially on exit vehicles based on the chassis Renault Midlum, during the period 2006 - 2013. These vehicles were operated by professional units of the Fire and Rescue Service of the Zlin Region. The paper's aim is to specify the optimum lifetime of the fire-fighting vehicles by the marginal analysis of fire-fighting vehicles' economical operation. Theoretic calculations of the optimum lifetime have been processed with implementing both the method of exponential trends, and Brown method. The residual value of vehicles has been calculated both according to the current Czech tax law, and to the Expert Standard Valuation of motor vehicles in force in the Czech Republic.*

**Keywords:** Acquisition value; costs; amortization; residual value; economic life.

### 1. Introduction

This paper follows on previous publications of the author focused on the functional reliability assessment of Firefighting and Rescue Appliances based on the chassis Renault Midlum [1, 2 and 3]. These vehicles were deployed at professional units of the Fire and Rescue Service of the Zlin Region during the reporting period. Results of alternative calculations of theoretical economic lifetime are presented in this paper.

### 2. Characteristics of observed Firefighting and Rescue Appliances

Key operational and economic characteristics of the monitored equipment for the period 2005-2013 are given in Table 1. Basic tactical and technical characteristics of vehicles type Renault Midlum 270.14 P 4x4, for example, can be traced in the literature [3 and 4].

Basic characteristics of referred vehicles during years 2005-2013

Table 1

Vehicle dislocation	Registration mark	Date of commissioning	Purchase price [CZK]	Mileage [km]	Machine work at the site [hour]	Amount of fuel [litr]	Repair costs [CZK]
Zlin	2Z7 8478	20/09/2006	5 805 200	31 278	328	7 264	304 644
Zlin	3Z3 4693	17/12/2007	5 000 000	23 490	112	4 561	201 366
Slavicin	3Z5 7550	16/12/2008	5 000 000	9 993	223	3 868	97 669
Otrokovice	2Z7 8479	20/09/2006	5 805 200	22 860	407	6 632	331 197
Valasske Mezirici	2Z6 2647	20/02/2006	5 805 200	39 260	670	8 141	369 931
Valasske Mezirici	3Z5 7540	17/12/2008	5 000 000	10 241	97	3 721	99 661
Valasske Mezirici	3Z3 4692	14/12/2007	5 000 000	14 618	96	2 856	209 404
Uhersky Brod	3Z2 3957	30/12/2007	5 307 400	28 908	479	9 314	211 802
Uherske Hradiste	3Z6 6297	05/01/2009	5 307 400	15 584	415	6 780	213 246

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### 3. Methods

Primary operating data [5] for the years 2010-2013 received from the information system IKIS II, were exported to Excel file format and used for failure rate of monitored vehicles evaluating. Data for the years 2005 to 2009 were investigated by the author personally from machinery service records at individual Regional Departments of the Zlin region.

*Service life* is the ability of the technical system to perform desired functions in order to achieve the ultimate state [6]. *Economic life* of the vehicle can be generally characterized as reaching the limit state when further operation is economically unsustainable [7].

The *economic efficiency of the investment* is calculated to assess the economic life of the technical system in the business environment. This procedure would be relatively difficult to apply for the evaluation of firefighting appliances. The methodology of these calculations is based on the input data extremely difficult to define in the sphere of public service [8 and 9]. Expected annual returns and/or annual operating costs in dealing with accidental incidents are representatives of these data. Revenues are primarily represented by preserved properties during the liquidation of accidents. Property owners and insurance companies usually have different views on the amount of damages. Forensic expert opinion and/or the court proceedings decide in these disputes thereafter. The total amount of investment, bank loans, the tax rate for the calculation of investment income taxes and annual depreciation might be examples of detectable data. Further reason for the impossibility of using this calculation method is the requirement of the initial setting of the technical system's lifetime. The approximate lifetime can be only theoretically assumed from the Machinery Service Order [10].

Therefore, the calculation of the monitored vehicles' economic life was performed by use of two simple and generally known methods, both *exponential trends method*, and the *Brown method* [11 and 12]. Calculations according to both methods were performed for 5-year operation time period. The *residual value* of appliances, which is one of data used for calculations, was variously calculated according to the Act No. 586/1992 Coll. on Income Taxes [13], and according to the Expert Standard No. I/2005 - Valuation of motor vehicles [14].

#### 3.1. Exponential trend method

The exponential trends method is based on the theoretical assumption that the value of firefighting appliances in time  $N_p(t)$  has the shape of downward sloping exponential curve [11]. The curve is defined by the equation:

$$N_p(t) = C \cdot e^{-\alpha t} \quad (1)$$

Similarly, we can define by using an upward sloping exponential curve the trend of costs for maintenance and repairs  $N_u(t)$  according to the equation:

$$N_u(t) = A \cdot e^{\beta t} \quad (2)$$

The total value of firefighting appliances  $N_c(t)$  is a sum of equations (1) a (2):

$$N_c(t) = C \cdot e^{-\alpha t} + A \cdot e^{\beta t} \quad (3)$$

Further, we can count the local extreme of the function (3) by derivation. The local extreme ( $N_c(t)$  minimum in this case) represents the optimal time  $T_{opt}$  for replacing the appliance:

$$T_{opt} = \frac{1}{\alpha + \beta} \cdot \ln\left(\frac{\alpha \cdot C}{\beta \cdot A}\right) \quad (4)$$

After reaching the minimum point the function  $N_c(t)$  rises, due to declining price of the firefighting vehicle  $N_c(t)$  and increasing maintenance and repair costs  $N_u(t)$ . The constants  $A$ ,  $C$  and exponent coefficients  $\alpha$ ,  $\beta$  are obtained after processing the input of economic data, building charts and drawing or exponential curve of these charts by using appropriate software, e.g. MS Excel.

#### 3.2. Brown method

This method was first published over 55 years ago in the journal *Railway Age*, in Brown's paper "What's the Life of a Diesel?" Theoretical foundations were then summarized and published in 1963 [15]. The method was used for the preliminary determination lifetime of rail vehicles [11]. The optimum lifetime  $T_{opt}$  is given by:

$$T_{opt} = \sqrt{\frac{2 \cdot H_0}{B}} \quad (5)$$

Here,  $H_0$  is the vehicles' acquisition value given as a percentage = 100 % and  $B$  is the linear incremental trend coefficient of the maintenance and repair costs. This coefficient is obtained likewise from the charts using linear regression of data. Application of this method is connected with some weaknesses, as discussed below in the results.

#### 3.3. Vehicle's residual value calculations

Calculations of the vehicle's residual value according to the Act on Income Tax [13] consider the depreciation period of 5 years in Article 30 within motor vehicles for special purposes, according to the classification in Appendix No. 1 of the Act. Depreciation percentages are fixed for the first year at the level

of 11% and for the next four years they are changed to 22.25%. Calculating the relative technical value of the vehicle *PTHS* in any year of operation is carried out in a percentage of the purchase price, in accordance with the Expert Standard [14], by the equation:

$$PTHS = \frac{THSN \cdot (100 - ZA) \cdot (100 \pm TS) \cdot PDS}{10^6} \quad (6)$$

Initial technical value of the group *THSN* = 100%, technical condition changes *TS* = 0.0% and the relative group proportion value *PDS* = 100% were applied in the equation, in the case of maintained and operational firefighting appliances. Basic amortization *ZA* [%] which is calculated as the arithmetic average of the following equation was the only variable in the equation (6):

$$ZA = \frac{ZAD + ZAP}{2} \quad (7)$$

*ZAD* parameter is the basic percent reduction during the operation defined in Annex No. 1.4 of the Expert standard [14] and ranges from 20% in the first year of operation to 90% in the tenth and following year of operation. *ZAP* parameter [%] determines the percentage of the basic reduction for the mileage (see *ibid.*).

#### 4. Results

Overall results of calculations are stated in the following tables and graph exemplifications of which are evident constants and coefficients exponents values used for the calculations in equations (4) and (5).

The difference of calculated results of the vehicle's residual value was set in Figs. 1 and 2, as demonstrated on the case of the vehicle registration number 3Z2 6957, deployed at the fire station Uhersky Brod. It is evident that the Expert Standard is more suitable for both longer amortization time, and mileage consideration. These factors can significantly affect the vehicle wearing. Expert Standard gives even higher residual value of the particular vehicle in the final outcome.

The difference in resulting functions of repair costs (for the same vehicle) obtained by the method of exponential trends and Brown's method can be seen in Figs. 3 and 4. The vehicle registration number 3Z2 3957 of the station Uhersky Brod was chosen as an example because due to the highest calculated value of economic life, which is closest to the expected present reality. The appliance was included into exit vehicles on December 31, 2007. Unfortunately, even in these calculations is reflected the fact that operation records were not conducted complexly before 2010 [1 and 2]. Thus, it was found that the vehicle mileage had reached 13,600 km in years 2008 and 2009 but recorded repair costs had been zero in the same period.

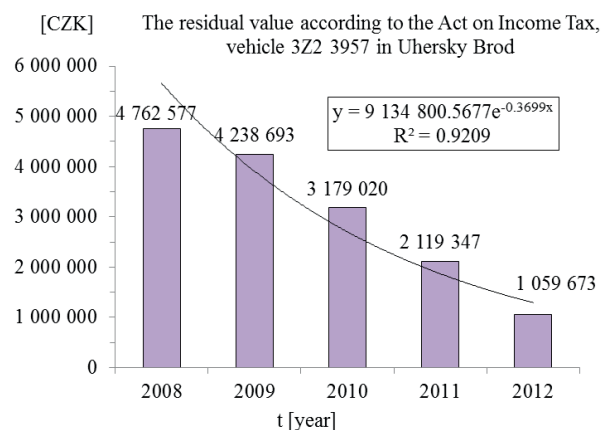


Fig. 1 The residual value according to the Act on Income Tax

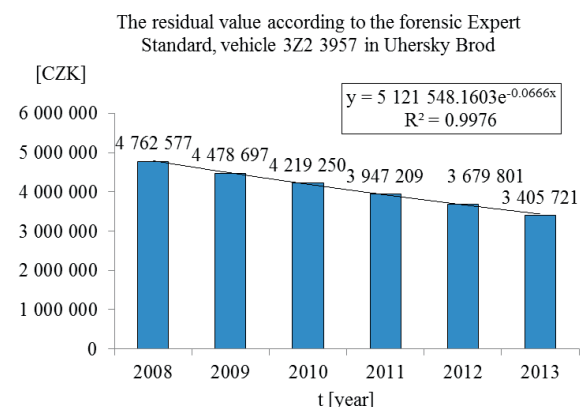


Fig. 2 The residual value according to the forensic Expert Standard

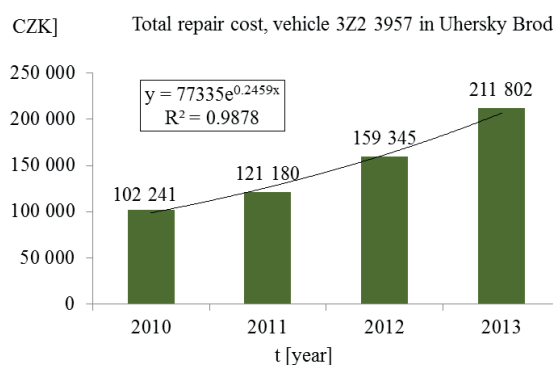


Fig. 3 Total repair costs according to the exponential trends method

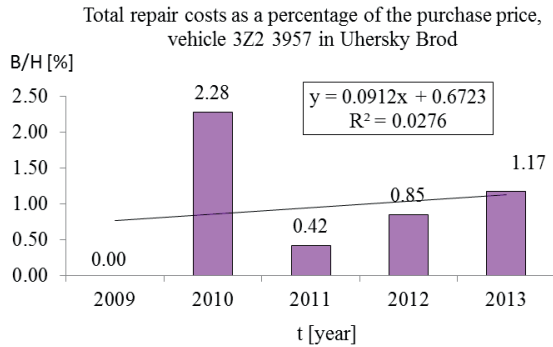


Fig. 4 Repair costs according to the Brown method

Results of the recovery time when depreciating according to the Act on Income Tax are shown in Table 2 [13]. Table 3 presents alternative results of calculations while using the depreciation according to the Expert Standard [14]. Both results are counted when applying the method of exponential trends. As written above next to Figs. 1 and 2, the influence of valuation methods is reflected in the final size of the recovery time.

Results acquired by the Brown method with using linear trends are shown in Table 4. Calculations show that the Brown method application is inappropriate for fire equipment. Calculation results are completely out of reality. Correlation coefficients of each regression curve are very low. The optimal economic life calculations by the equation (5) for negative values of constant  $B$  cannot be accomplished thereafter.

Recovery time in accordance with the Brown method Table 4

Vehicle dislocation	Registration mark	$B$ [-]	Correlation coefficient $R$	$T_{opt}$ [year]
Zlin	2Z7 8478	0.2871	0.4303	26
Zlin	3Z3 4693	-0.0119	0.0608	
Slavicin	3Z5 7550	0.042	0.1682	69
Otrokovice	2Z7 8479	0.1074	0.1327	43
Valasske Mezirici	2Z6 2647	-0.1507	0.1503	
Valasske Mezirici	3Z5 7540	0.0787	0.3746	50
Valasske Mezirici	3Z3 4692	0.4995	0.7030	20
Uhersky Brod	3Z2 3957	0.0769	0.1661	51
Uherske Hradiste	3Z6 6297	0.3754	0.9027	23

Using this method has its disadvantages. The method was formulated for rail vehicles, which have high initial costs, and the expected optimum life is considerably longer than 10 years. For

Recovery time in accordance with the Act on Income Tax

Table 2

Vehicle dislocation	Registration mark	Maintenance and repairs cost ratio $N_u(t)$			Residual value of firefighting appliances in time $N_p(t)$ coefficients			$T_{opt}$ [year]
		$A$ [CZK]	$\beta$ [-]	Correlation coefficient $R$	$C$ [CZK]	$\alpha$ [-]	Correlation coefficient $R$	
Zlin	2Z7 8478	36 512	0.5899	0.907	8 444 634	0.3699	0.960	5.2
Zlin	3Z3 4693	37 561	0.3529	0.961	7 660 778	0.3699	0.960	7.4
Slavicin	3Z5 7550	27 164	0.3397	0.909	8 605 720	0.3699	0.960	8.2
Otrokovice	2Z7 8479	64 958	0.4619	0.890	8 453 027	0.3699	0.960	5.6
Valasske Mezirici	2Z6 2647	32 249	0.5644	0.832	7 926 425	0.3699	0.960	5.4
Valasske Mezirici	3Z5 7540	4 763	0.6637	0.952	8 605 720	0.3699	0.960	6.7
Valasske Mezirici	3Z3 4692	3 447	0.7005	0.966	7 715 162	0.3699	0.960	6.6
Uhersky Brod	3Z2 3957	77 335	0.2459	0.994	9 134 800	0.3699	0.960	8.4
Uherske Hradiste	3Z6 6297	23 196	0.5493	0.999	9 134 800	0.3699	0.960	6.1

Recovery time in accordance with the Expert Standard

Table 3

Vehicle dislocation	Registration mark	Maintenance and repairs cost ratio $N_u(t)$			Residual value of firefighting appliances in time $N_p(t)$ coefficients			$T_{opt}$ [year]
		$A$ [CZK]	$\beta$ [-]	Correlation coefficient $R$	$C$ [CZK]	$\alpha$ [-]	Correlation coefficient $R$	
Zlin	2Z7 8478	36 512	0.5899	0.907	5 553 636	0.0638	0.9982	4.3
Zlin	3Z3 4693	37 561	0.3529	0.961	4 779 616	0.0631	0.9987	7.5
Slavicin	3Z5 7550	27 164	0.3397	0.909	4 822 246	0.0652	0.9989	8.7
Otrokovice	2Z7 8479	64 958	0.4619	0.890	5 565 664	0.0637	0.9980	4.7
Valasske Mezirici	2Z6 2647	32 249	0.5644	0.832	5 655 152	0.0704	0.9894	4.9
Valasske Mezirici	3Z5 7540	4 763	0.6637	0.952	4 795 414	0.063	0.9993	6.3
Valasske Mezirici	3Z3 4692	3 447	0.7005	0.966	4 779 616	0.0631	0.9987	6.3
Uhersky Brod	3Z2 3957	77 335	0.2459	0.994	5 121 548	0.0666	0.9988	9.2
Uherske Hradiste	3Z6 6297	23 196	0.5493	0.999	5 095 852	0.0641	0.9996	5.3

example, rail kit CityElefant type 471/071/971 costs CZK 217 million within the lifetime of 30 years or rail kit RegioSprinter BR 654 costs CZK 47 million within the lifetime of 25 years. Application of this method assumes steady and in time rising repair costs. To evaluate the lifetime of less costly firefighting equipment, then the results are not those we expected.

## 5. Conclusion

Calculations results show that we can theoretically expect the optimum lifetime close to 9 years operation of firefighting vehicles based on the chassis Renault Midlum. This theoretical aim was achieved without major problems in six of the nine observed trucks. This lifetime depends on the current operational load. The

firefighting vehicle lifetime can be prolonged by relocating trucks from the group of emergency vehicles to reserves that are in lower service load. Using the Expert Standard for more accurate and more realistic residual vehicle value determination than using the Act on Income Tax is the next recommendation. Confirmation of the Brown method unsuitability for these calculations is the last major finding.

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