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TESTING THE LOGISTICS MODEL OF SUPPLYING MILITARY VEHICLES WITH SPARE PARTS

ABSTRACT

The use of advanced transport means understands also their supply by spare and consumable parts. In order to solve the problem of the required quantities, costs of purchase and storage of the parts, it is necessary to solve the problem of stocks management. The wear of tyres for military vehicles in extreme exploitation conditions is of random character. How fast the tyres will wear on the all-terrain and heavy motor vehicle depends on the driver's skill and the external conditions (weather, terrain). All the conditions are of random character and in order to determine as accurately as possible the wear of tyres it is necessary to monitor the wear of tyres within a certain time period, and to find the approximate probability of tyre wear in the future period of time. When the probability of tyre wear is determined, stochastic supply management model is used to calculate the value of the stocks which allows optimal planning of stocks of spare parts at minimal costs. The stochastic model allows optimal calculation for the purchase of consumable parts of transport means whose consumption depends on the random conditions and events.

KEY WORDS

stocks, supply, stochastic model, spare parts

1. INTRODUCTION

Motor vehicles of the Croatian Army are extremely complex regarding design, built in a conventional (non-modular) way, of very compressed structure, with a large number of dependent construction and functional connections. Most failures of motor vehicles used in the Croatian Army are not the result of fatigue or excessive wear, but of random loadings, impacts due to off-road movements, incorrect handling and other factors in peacetime period, whereas in war activities the mentioned malfunctions are equal in quantity. Another type of malfunction is conditioned by structural loadings (age, corrosion), especially expressed in non-metals.

According to research of the duration of repairs of military motor vehicles in the period of 10 years the advantages of preventive and corrective maintenance of the level of small, medium and general overhaul have been noticed with greater or smaller disassembling of motor vehicles into components, necessary depth of the interventions and intensity of failures of the components. The activities are performed in war and peacetime conditions, at an adequate repair shop and with relatively experienced workforce. In [5] it has been proved that the largest indicated losses are precisely the result of waiting and shortage of spare parts, and this article deals with the prevention thereof. Similar methods have been analysed in [4].

2. PLANNING OF OPTIMAL STOCKS AND COSTS OF PURCHASING SPARE PARTS FOR MILITARY VEHICLES

Let $p(x) \in [0,1]$ be the distribution of the probability of random variable x, which indicates the number of worn parts (tyres). It is necessary to know C_1- costs of purchasing stocks and C_2- costs of extra purchase of stocks. The total costs (Z) for the quantity of stocks (y) are calculated by formula:

$$Z = Z(y) = C_1 \sum_{x=0}^{y}(y-x)p(x) + C_2 \sum_{x=y+1}^{\infty}(x-y)p(x) \quad (1)$$

The quantity of stocks y, in which the value of function Z(y) is minimal, meets the following inequalities:

$$Z(y)<Z(y-k) \text{ and } Z(y)<Z(y+k) \tag{2}$$

where k represents the excess or shortage regarding the optimal number of tyres at the warehouse.

By inserting the expressions from formula (2) into formula (1), the following formulae are obtained:

$$Z(y-k)=C_1\cdot\sum_{x=0}^{y-k}(y-k-x)p(x)+$$
$$+C_2\cdot\sum_{x=y-k+1}^{\infty}(x-y+k)p(x)$$

$$Z(y+k)=C_1\cdot\sum_{x=0}^{y+k}(y+k-x)p(x)+$$
$$+C_2\cdot\sum_{x=y+k+1}^{\infty}(x-y-k)p(x)$$

The optimal quantity of stocks is given by formula (see in [8]):

$$F(y)=\frac{C_2}{C_1+C_2} \tag{3}$$

where $F(y)=\sum_{x=0}^{y}p(x)$ is the value of the distribution function of random variable x for arbitrary y.

The costs for a certain quantity of stocks y, will be:

- (y-x) C_1, if $x\le y$ i. e. if stocks are greater than the quantities of the worn parts,
- (x-y) C_2, if $x>y$ i. e. when there are not enough quantities of spare parts on stock.

3. EXAMPLE:

The given values are the consequence of the relation between supply and demand on the market and the assessment of additional costs in case of the need for urgent purchase:

- price of one spare part, in case of regular order C_1 = HRK 800,
- price of one spare part, in case of subsequent order C_2 = HRK 2500,
- consumption of spare parts p(x) can be seen from the following table:

Table 1

X	0	1	2	3	4	5
P(x)	0	0.05	0.08	0.09	0.1	0.13
X	6	7	8	9	10	Σ
P(x)	0.23	0.12	0.1	0.05	0.05	**1.00**

The values from Table 1 have been obtained by statistical monitoring of the consumption of tyres for 20 off-road - heavy vehicles, and refer to the time period of one month.

Testing the model of determining the optimal quantities of stocks y which is indicated in (3) consists in immediate calculation of purchase costs for all the possible values of fix stock quantities.

$$Z(10)=800\sum_{x=0}^{10}(10-x)p(x)+0=\underline{3600\text{ kn}}$$

$$Z(9)=800\sum_{x=0}^{9}(9-x)p(x)+2500\sum_{x=10}^{10}(x-9)p(x)=$$
$$\underline{2965\text{ kn}}$$

$$Z(8)=800\sum_{x=0}^{8}(8-x)p(x)+2500\sum_{x=9}^{10}(x-8)p(x)=$$
$$\underline{2495\text{ kn}}$$

$$Z(7)=800\sum_{x=0}^{7}(7-x)p(x)+2500\sum_{x=8}^{10}(x-7)p(x)=$$
$$\underline{2355\text{ kn}}$$

$$Z(6)=800\sum_{x=0}^{6}(6-x)p(x)+2500\sum_{x=7}^{10}(x-6)p(x)=$$
$$\underline{2611\text{ kn}}$$

$$Z(5)=800\sum_{x=0}^{5}(5-x)p(x)+2500\sum_{x=6}^{10}(x-5)p(x)=$$
$$\underline{3626\text{ kn}}$$

$$Z(4)=800\sum_{x=0}^{4}(4-x)p(x)+2500\sum_{x=5}^{10}(x-4)p(x)=$$
$$\underline{5070\text{ kn}}$$

$$Z(3)=800\sum_{x=0}^{3}(3-x)p(x)+2500\sum_{x=4}^{10}(x-3)p(x)=$$
$$\underline{6844\text{ kn}}$$

$$Z(2)=800\sum_{x=0}^{2}(2-x)p(x)+2500\sum_{x=3}^{10}(x-2)p(x)=$$
$$\underline{7891\text{ kn}}$$

$$Z(1)=800\sum_{x=0}^{1}(1-x)p(x)+2500\sum_{x=2}^{10}(x-1)p(x)=$$
$$\underline{11250\text{ kn}}$$

$$Z(0)=2500\sum_{x=1}^{10}xp(x)=\underline{11950\text{ kn}}$$

The calculation shows that it is optimal to plan the stock quantity of $y=7$ tyres for heavy – off-road vehicle, which will stipulate the minimal costs.

The optimal quantity of stocks can be calculated by means of the following relations:

$$F(y-1)=\sum_{x=0}^{y-1}p(x)\le\frac{C_2}{C_1+C_2}\le\sum_{x=0}^{y}p(x)=F(y) \tag{4}$$

The distribution function F(y) is given as a table from experimental data:

Table 2

X	0	1	2	3	4	5
F(x)	0	0.05	0.13	0.22	0.32	0.45
X	6	7	8	9	10	
F(x)	0.68	0.80	0.90	0.95	**1.00**	

By inserting C_1 and C_2, the following is obtained:

$$F(y)=\frac{C_2}{C_1+C_2}=\frac{2500}{800+2500}=0.7576$$

Due to the natural requirement, the quantity of stocks has to be an integer, and it is therefore calculated according to:

$$F(y-1)\leq 0.7576\leq F(y).$$

From the data from the previous table, the optimal quantity is y = 7, whereas minimal costs amount to Z(y) = HRK 2355.

The comparison of calculation values shows that a smaller quantity of stocks in relation to the optimal one causes an increase in the costs of purchasing the spare parts. With a greater quantity of stocks than the optimal quantity the costs increase but to a smaller extent. If a minor deviation from the optimal quantity is expected in terms of the increase in the quantity of the necessary spare parts, it shows that lower costs are created by a greater quantity of extra purchase of the spare parts.

4. CONCLUSION

Good supply management in the Croatian Army represents an increase in the reliability of the system, which is an essential precondition for the system to be cost-efficient. It is known that from [2] the average quantity of supplies directly affects the cost-efficiency of the system, since substantial capital is tied up in supplies, which reduces the quantity of free capital on the market. The quantity and turnover of free capital on the market are directly related to the cost-efficiency of the system (see in [1] and [4]). Although the army is not an economic category of the society in the sense of profit-making, [8] shows that the supply management in military organization has a great significance due to the requirement of high combat readiness and limited material possibilities of the country.

Spare parts regarding stocks in the supply system of the Croatian Army represent a significant element of logistics insurance. Work [8] shows that the availability coefficient will be higher if the time of standstill is shorter, i. e. in case of a shorter time of keeping the material technical means in the technical workshop. This period, when the material technical means are in the technical workshop for repair or preventive maintenance (standstill) reduces the combat readiness of the unit. The time that material technical means stay at the technical workshop or overhaul institute, is significantly affected by the insurance of adequate quantities and range of spare parts.

The calculation of the optimal quantity of supplies reduces the costs of purchase and storage, and the accurate calculation of costs based on the optimal quantity of supplies allows optimal planning of the purchase of all the consumable parts.

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SAŽETAK

TESTIRANJE LOGISTIČKOG MODELA OPSKRBE VOJNIH VOZILA PRIČUVNIM DIJELOVIMA

Uporaba suvremenih prijevoznih sredstava podrazumijeva i opskrbu istih pričuvnim i potrošnim dijelovima. Kako bi se riješio problem potrebnih količina troškova nabave i skladištenja dijelova potrebno je riješiti problem upravljanja zalihama. Potrošnja guma za vojna vozila u ekstremnim uvjetima eksploatacije slučajnog je karaktera. Koliko će se gume brzo trošiti na terenskom i teretnom motornom vozilu ovisi o vještini vozača, te vanjskim uvjetima (vrijeme, podloga terena). Svi uvjeti su slučajnog karaktera i kako bi se što približnije odredila potrošnja guma potrebno je pratiti potrošnju guma u određenom vremenskom razdoblju, te pronaći približnu vjerojatnost potrošnje guma u budućem vremenskom razdoblju. Kada se odredi vjerojatnost potrošnje guma, stohastičkim se modelom upravljanja zalihama izračunava vrijednost zaliha koja omogućava optimalno planiranje zaliha pričuvnih dijelova s minimalnim troškovima. Stohastički model omogućuje optimalan proračun za nabavu potrošnih dijelova transportnih sredstava čija potrošnja ovisi o slučajnim uvjetima i događajima.

KLJUČNE RIJEČI

zalihe, opskrba, stohastički model, pričuvni dijelovi

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