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STATE AND PROBLEMS OF THE SYSTEM FOR MACHINERY REPAIR SERVICE IN BULGARIAN FORESTRY

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Abstract: *The analysis of the state of the forestry machinery repair service in Bulgaria shows that kind of machinery results of both wear and tear and obsolescence state, being the activity of its maintenance in efficiency embarrassed by the intense decentralization occurring in more than 3000 companies. To keep the machinery efficiency on, in a good state, for being reliably utilized in the future, a system for repair service (both technical service TS and repair R comprised) is to be elaborated which principal elements are as following ones: the optimization of the periodicity of machinery elements technical service and the repair.*

1. Introduction

The development stages of the machinery technical service (TS) and repair (R) are shown in Figure 1. It results as from the data analysis of the information, shown by the scheme, which way shall be followed, further on, for the development and improvement of the machinery technical service and repair.

When an estimation of the coefficient of variation of the sample - to - rejection (ϑ) is made, proceeding from the heuristic considerations (Tasev, 2002), a family of n-densities may be input for distribution, as $\{f_1(t),f_2(t),\ldots,f_n(t)\} \in f(t)$, i.e. if $0< \vartheta \leq 0{,}33$, the distribution density results in accordance with the normal law; being $0{,}33< \vartheta \leq 0{,}5$ accordingly to Weibull`s or to the normal law; $0{,}5< \vartheta \leq 1{,}0$ accordingly to Weibull`s law; $\vartheta =1{,}0$ accordingly to the exponential law; $\vartheta >1{,}0$ - accordingly to Weibull`s law of the distribution (Spiridonov et al. 1980).

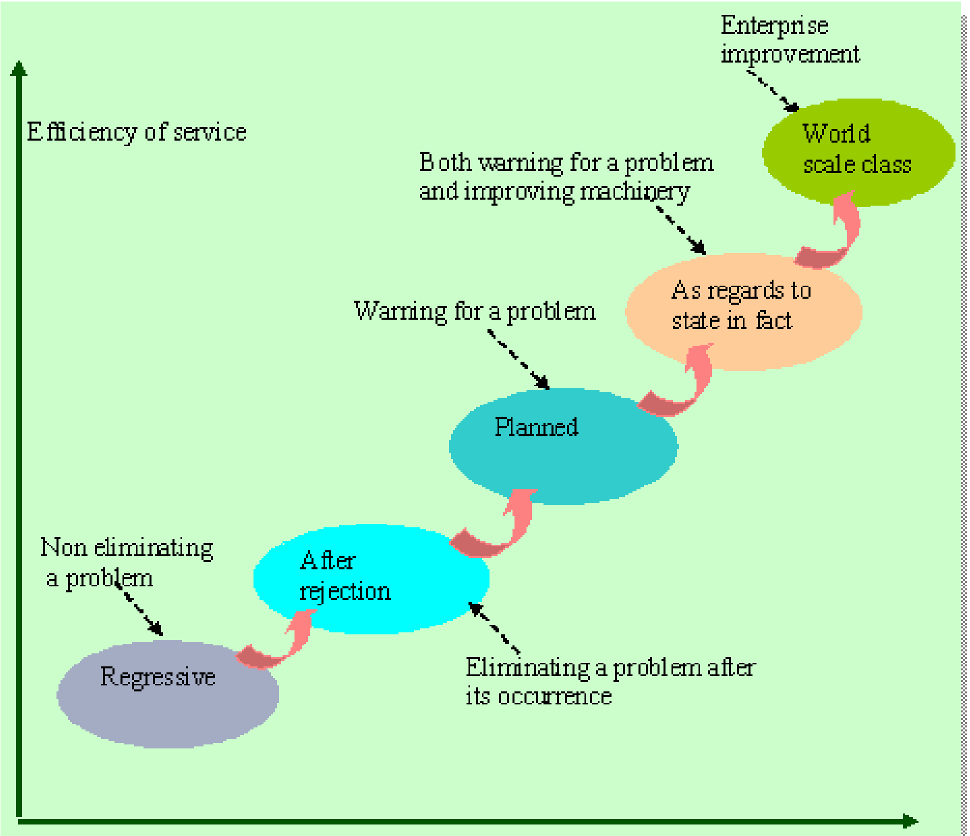
Thus, after minimizing the prognosticated specific expenses, a contingent evaluation and a calculation of the optimum values of the planned technical service (PTS) may be made, but, due to the acceptance *a priori* of the respective law of distribution of the element (sample – to - rejection) index of reliability, an error omitting optimum value of the planned technical service (PTS) shall be selected, as regards to the specific expenses.

That is why, having recourse to the property of the solutions economic stability, when an input error of the specific exploitation expenses is provided, as, for example, 3-5%, the range of the optimal (equivalent as regards to the economical indices) values of the planned technical service (PTS) may be determined, for any density of distribution of the sample – to - rejection.

That mathematical approach, which is being proposed, will be studied when a strategy of the sample – to – rejection replacement is applied to, being the specific exploitation costs, as following below:

$$C(\tau) = [C_0 - (C_0 - C_n)P(\tau)] / \int_0^{\tau} P(t)dt \qquad (1)$$

where: Co and Cn are expenses resulted from the replacement due to rejection and from the planned repair effect, respectively; τ represents the periodicity of a planned technical service (PTS) to be provided; P(τ) means a probability for a faultless work.



Expected result	Short term economics	Over contracted works	No surprises occurred	Enhanced competitive-ness	Appearance at international level
Motive forces	Corresponding planned budget	Shortage of idle time	Warning for rejection/s	Increased ratio of technical utilization	Development
Method of acting	Inactivity	Reaction to the arisen problem	Planned technical service anc repair	High - degree labor organization discipline	Organization in the course of training

Figure 1: **Stages of development of the system for technical service (TS) and repair (R)**

When the expression (l) is reduced to a non dimensioned one, by dividing it to CoT^{-1} where T means the average sample – to - rejection, a result, as following below, will be obtained from:

$$\phi = \frac{C(\tau)T}{C_0} = \frac{1-(1-\gamma)P(x)}{\int_0^x P(UT)dU} \quad (2)$$

where Φ means the relative specific exploitation costs; ŋ = $CnCo^{-1}$ is the expenses ratio; x= τT^{-1} the periodicity of the technical service;U= tT^{-1} time correlated to the average sample to rejection.

It is known, when that strategy of the technical service is applied to, the optimum periodicity is expressed by an aliquot (multiple), if P(U) means a distribution of an increasing function of rejections intensity h(t) and the condition $\vartheta<1-\gamma$ (Spiridonov et al. 1980) results fulfilled. It is evident, as by the studies conducted, the sample – to – rejection and the resource of the elements of tractors, cars and agricultural machines, are well described using a normal, Weibull`s and a gamma distribution (Tasev, 2002). That is a motivation, when a partial indeterminateness is found, as of the output data, the above cited three laws to be used for the purpose, as following ones, respectively:

$$P_н(U)=[F_o(1-U)/\xi)][F_o(1/\xi)]^{-1};\ Pb(U)=exp[-(UK_b)^b] \quad (3)$$

$$P\gamma(u) = [\exp(-mU)]\sum_{i=1}^{m-1}(mU)^i / i! \quad (4)$$

where F_o is the tabulated function of the normal distribution; b the parameter of the Weibull` s distribution form; $K_b=\gamma\ (1+b)^{-1}$; γ the gamma function; m the parameter of the gamma distribution form.

When the coefficient of variation ξ is known, the parameter of the form b and K_b are to be found in the respective table, while the parameter $m=\xi^{-2}$ is to be rounded to the nearest integer.

Further on, a substitution of P (U) in the expressions (2) and (3) shall be made, and the mathematical models will result from, to be applied to, for the optimization of the planned technical service (PTS) in the above described family of distribution of the sample – to - rejection of the elements.

Hence, on the ground of the proposed mathematical approach, as the above expressed one, the following mathematical models result, as the given ones below:

a. $$\phi_{\mathrm{H}} = [1-(1-\eta)P(x)] / \int_0^x F_0((1-U)/\xi)][F_0(1/\xi)]^{-1}dU \quad (5)$$

b. $$\phi_{\mathrm{H}} = [1-(1-\eta)P(x)] / \int_0^x \exp[-(UK_b)^b]dU \quad (6)$$

c. $$\phi_{\mathrm{H}} = [1-(1-\eta)P(x)] / \int_0^x \exp[-(mU)]\sum_{i=1}^{m-1}(mU)^I\, dU / I! \quad (7)$$

It is not only the optimal value x_o, that can be calculated, but also the lower ($\underline{x}_o$) and the upper ($\overline{x}_o$) value of the range of the technical service optimal periodicity in practice, determined at an error coefficient input, as regards to the specific exploitation costs (δ=1,05).
The results, obtained from the calculation, are given in Figure 2 and Figure 3; and, taking into consideration the analysis made, it follows:

1.As regards to the decrease of the coefficient of variation x_o, calculated as on the ground of the proposed models of different functions of the sample – to - reject, an approximation is being observed, as the difference among the functions of the examined families of distributions is being decreased.

2. As regards to the range of the optimal values of periodicity of the technical service (TS), in practice, i.e. [$\underline{x}_o \div \overline{x}_o$], for the examined families of distributions, a re-covering is being observed. In most of the cases, the value of x_o, calculated for different distributions, results "one into another". As, for example, x_o calculated for the gamma distribution and the normally segmented distribution, is within the range [$\underline{x}_o \div \overline{x}_o$], calculated for the Weibull`s distribution, by b = 2,1; $\vartheta$ = 0,5; when $\eta \geq 0,05$; and by b = 2,9; $\vartheta$ = 0,29 when $\eta \geq 0,02$. That is why, in practice, it results expediently, Weibull`s distribution to be applied to, as the calculations to be made are easier.

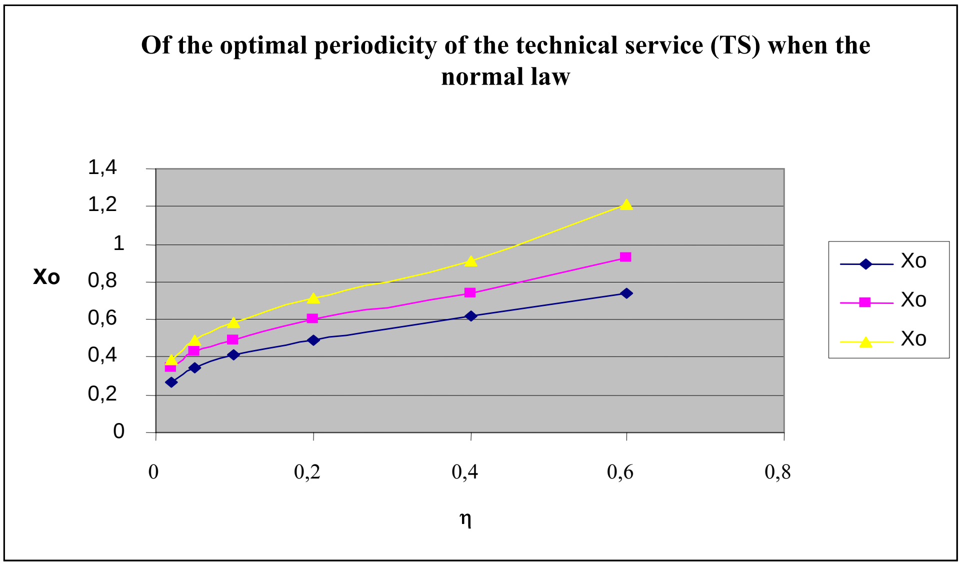


Figure 2: Alteration of the optimal periodicity of the technical service (TS) (Xo) as in function of the expenses ratio (η), - when the normal law of the distribution of the sample – to - rejection is applied,- and of the coefficient of variation V=0,5

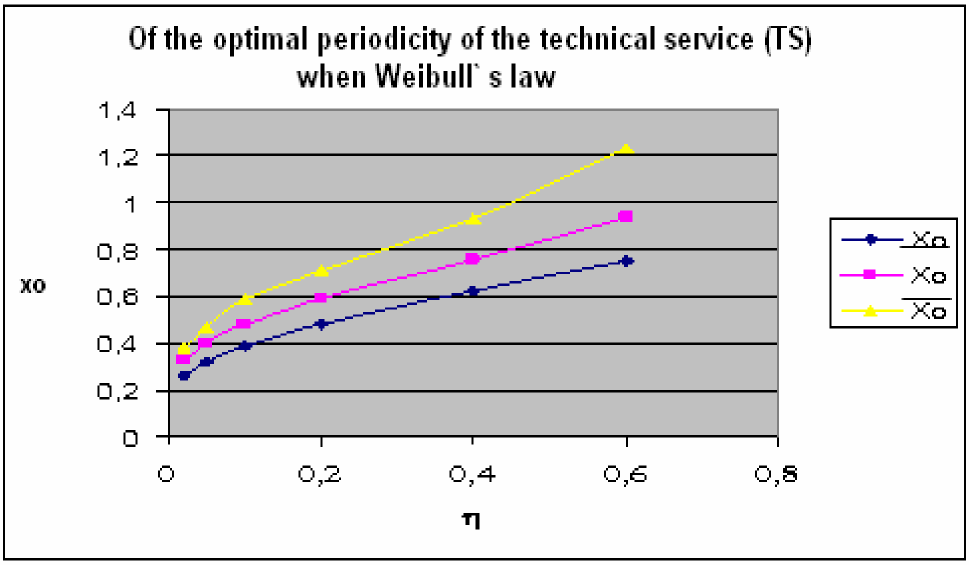


Figure 3: Alteration of the optimal periodicity of the technical service (TS) (Xo) as in function of the expenses ratio (η), - when Weibull` s law of the distribution of the sample- to - rejection is applied to,- and of the coefficient of the form b=2,1

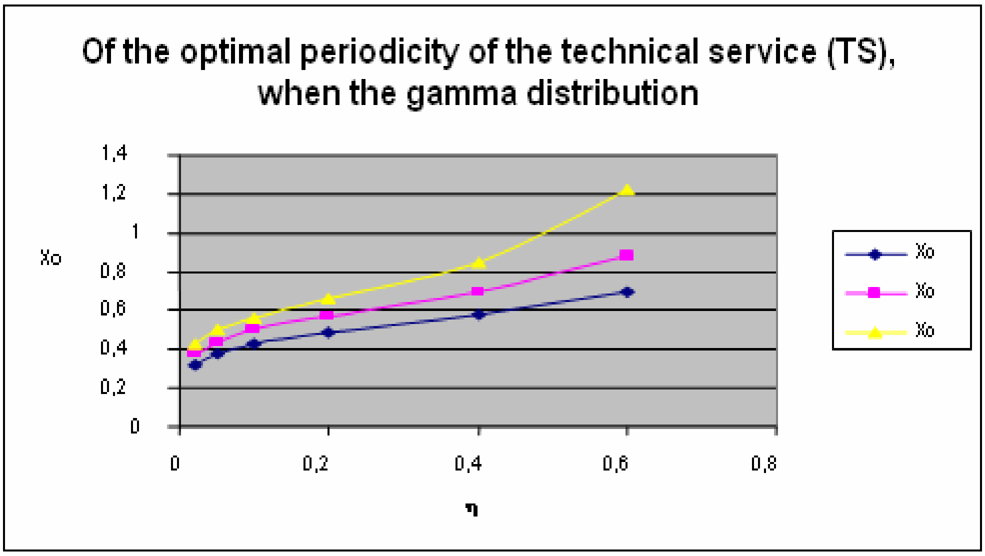


Figure 4: Alteration of the optimal periodicity of the technical service (TS)(Xo) as in function of the expenses ratio (η), - when the gamma distribution of the sample - to - rejection is used -, and of the coefficient of variation V=0,5

2. Elaboration of norms for the spare elements

To solve that problem, an expression of a determination of the rejections flow *H(t)* characteristics shall be made.

It has been established, for most of the elements of the machinery systems (machines and mechanisms) gradual rejections are being observed and uni-modal distributions, as well; and related to what above mentioned, it results necessary, functions of a universal type, complete and precise functions to be elaborated, as regards to the characteristics of the rejections flow, making thus possible the required fund of spare parts to be determined, as to provide for - and keep on - the machinery efficiency.

That is the motivation, a recurrent flow of permanent rejections to be examined, as a flow of discrete chance events in perpetual time (i.e. Erlang`s generic and special flow). Thus, it may be admitted, a selected distribution is the gamma type one, covering a vast range of uni-modal distributions. When $\lambda$ = 1, it is transformed into indicative; when $\lambda$ is an integer , it results identical to Erlang` s distribution.

When a recurrent flow of gradual rejections occurs, the characteristics of the flow of rejections will be of the type, as following below:

$$H_n(\lambda, s, t) = \lambda t - \frac{s}{2} + (1-s)\sum_{i=1}^{m} \exp\left[-\frac{\lambda t}{1-s} 2\sin^2 \pi i(1-s)\right]\frac{1}{\sin \pi i(1-s)} \cdot \sin\left[\frac{\lambda t}{1-s}.2\sin^2 \pi i(1-s) + \pi i(1-s)\right] + \frac{1-s}{2}\exp\left(-\frac{2\lambda t}{1-s}\right)\cos^2 \frac{\pi}{2(1-s)} \tag{8}$$

where s is the resource steadiness (the index characterizing the resource scattering measure approximating its average value) ($s = \frac{\alpha - 1}{\alpha} = 1 - v^2$; α-gamma distribution order (being α an integer of the Erlang` s distribution); ν the resource coefficient of variation; m harmonics number $m = \frac{(\alpha - 1 - \cos^2(\pi\alpha/2))}{2} = [s/(1-s) - \cos^2(\pi/(2(1-s)))]/2$

That formula, if applied to analytical purposes and practical calculations, may be simplified when it is admitted, all the components of the summary (total) harmonic are equal, being added the primary (basic) harmonic to:

$$H_n(\lambda, s, t) = \lambda t - \frac{s}{2}\left[1 - \exp\left(-\frac{\lambda t}{1-s} 2\sin^2 \pi i(1-s)\right)\frac{1}{\sin \pi(1-s)}.\sin\left(\frac{\lambda t}{1-s}.2\sin^2 \pi(1-s) + \pi(1-s)\right)\right] \tag{9}$$

3. Management of the elements resource

For an optimal management of the spare parts stock when an irregular use up of the spare elements is observed, i.e. the seasonal character of forestry production is taken into account, a mathematical model is proposed to be applied to. In such a case, an irregular use up of the spare elements is reported, and purchase expenditure and costs for stock completion depend upon the number of the elements.

It is necessary to precise such optimal number of shipments, where the summarized purchase and stock maintenance costs should be reduced to a minimum.

If the spare parts (SP) stock function is $Q_m(t)$, the cost of the elements Q within the period $[t_1;t_n]$ shall be calculated, using the formula, as following below:

$$Q = \int_{t1}^{t2} Qm(t)dt \tag{10}$$

The storage costs C_1 within the whole period $(0;t_n)$ will be

$$C_1 = \frac{S}{t_n}\left[\sum_{i=1}^{n} Q(t_i)(t_i - t_{i-1}) - \sum_{i=1}^{n}\int_{t_{i-1}}^{t_i} Q(t)dt\right] = \frac{S}{t_n}\left[\sum_{i=1}^{n} Q(t_i)\Delta t_i - \int_{t_0}^{t_i} Q(t)dt\right] \quad (11)$$

where S are the storage costs provided for a single element within the whole period, as from t_0 up to t_n.

The costs for the purchase of the i-batch of spare parts having a P1 volume can be represented as k + lPi, where k are costs non depending upon the elements number.

Hence, the purchase costs C_2 are as following below:

$$C_2 = k + lQ(t_1) + k + l[Q(t_2) - Q(t_1)] + ... + k + l[Q(t_n) - Q(t_{n-11})] = kn + lQ(t_n) \quad (12)$$

Then the summarized costs C will be, as following:

$$C = C_1 + C_2 = \frac{S}{t_n}\sum_{i=1}^{n} Q(t_i)\Delta t_i + kn + B = \frac{S}{n}\sum_{i=1}^{n} Q(t_i) + kn + B \quad (13)$$

where

$$B = lQ(t_n) - \frac{\text{S}}{\text{t}_\text{n}}\int_{t_0}^{t_n} Q(t)dt \quad (14)$$

Being t_0=0 and t_n = const, B is a constant that does not depend upon n; and when the lowest value of the summarized costs is to be calculated, it is enough, the expression $P(n) = \frac{S}{n}\sum_{i=1}^{n} Q(t_i) + kn$ at extreme to be examined.

When a function is of a type $Q_m(t)$ results as $Q_m(t) = Ae^{at_i}$, the expression P(n) will be, as following:

$$P(n) = \frac{S}{n}\sum_{i=1}^{n}\left(at + \frac{bt^2}{2} + \frac{\gamma t^3}{3}\right) + kn \quad (15)$$

Nullifying the first derivative of the expression P(n), a cubic equation will result from, as following $kn^2 - q = 0$, that will be easily solved by us analytically.

Its positive roots correspond to the extremum of the optimization function. If n results a non integer, it shall be rounded to a whole number. If there is an extremum of the function, that extremum will be minimum, and it will correspond to the required number of the shipments within the determined period.

When there is a function of the type as following: $Q_m(t)$, it will result as $Q_m(t) = Ae^{at_i}$, and the expression P(n) will be:

$$P(n) = \frac{S}{n}\sum_{i=1}^{n}\left(\frac{A}{a}e^{at_i}\right) + kn \quad (16)$$

Nullifying the first derivative of the expression P(n), a quadratic equation will result, as following: $kn^2 - q = 0$, that will be easily solved by us analytically.

Its positive roots correspond to the extremum of the optimization function. If n results a non integer, it shall be rounded to a whole number. If there is an extremum of the function, that extremum will be minimum.

In the course of the study, the optimal number of shipments (n) has been determined, within the period (tn), as regards to the above indicated storage costs amounts (s). The results of that study are given in Figure 5.

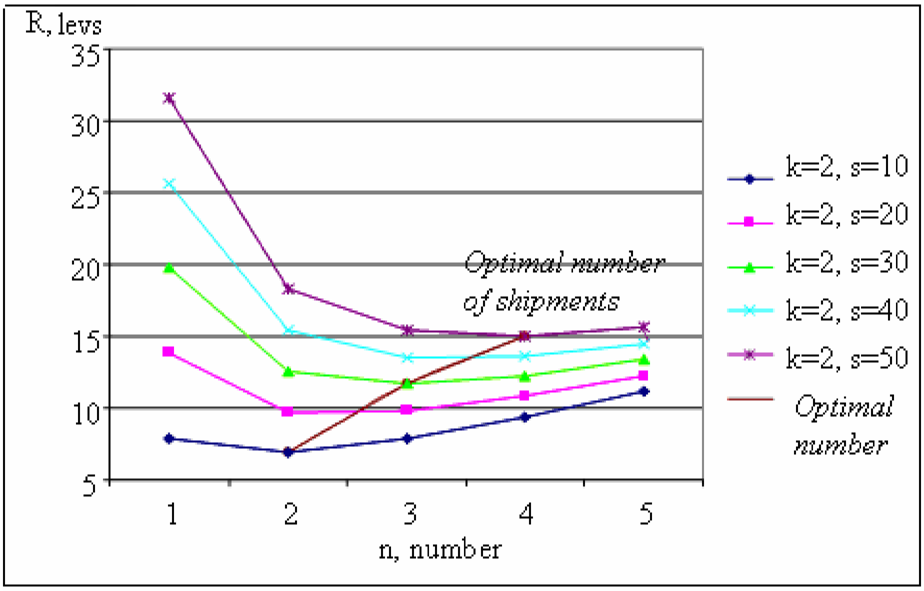


Figure 5: Optimal number of shipments (n) in a logistic system in function of storage costs (s) (1lev = 0,5 €)

In the course of the study, the optimal number of shipments (n) has been determined in a logistic system, as in function of the initial costs (k). The optimal values are given in Figure 6.

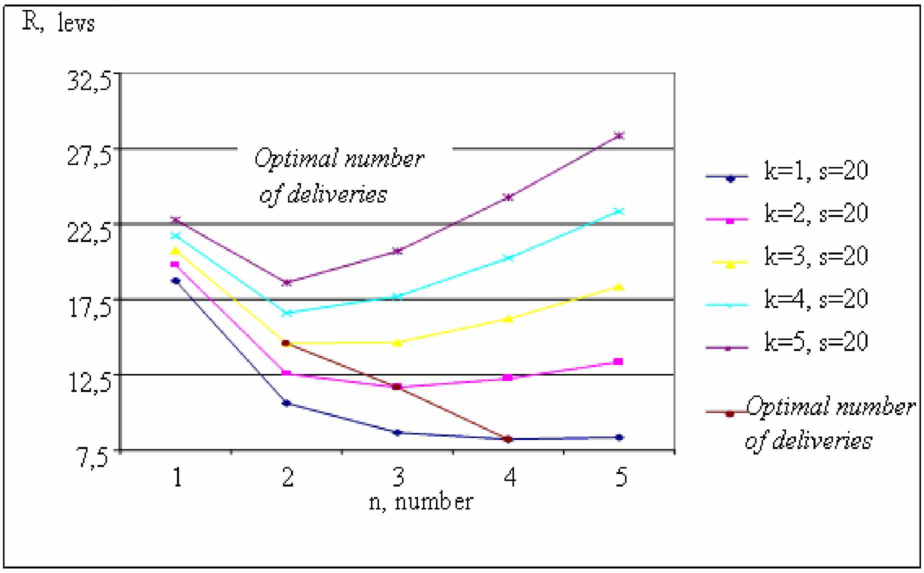


Figure 6: Optimal number of deliveries (n) in a logistic system as in function of the initial costs (к)

4. Conclusion

The methodical approaches, proposed herein, for optimization of the parameters of the system for technical service and repair, and for spare parts stock, that aims at keeping on the efficiency of the machines and machinery, used in forestry, will lead to a rapid development of the system for technical service and repair, thus providing, the latter one, from a system of maintenance and repair, to grow to a world scale one: which means, to the most efficient.

It will give a possibility to a substantial increase of the competitiveness of production and to a raise of the utilization ratio of the machinery, meanwhile providing for a high organizational and labor discipline to be kept.

An important moment is the above described machinery to be subdivided into two main groups:

- Second hand machinery (machines);
- Machines (machinery) that are new (recently produced), having the companies' producers their representatives in the country.

Each group has its own aspects that shall be reflected in the system for repair service.

5. References

Tasev, G. (2002) Reliability of machinery used in agriculture, Sofia.

Spiridonov, G. and Tasev, G. (1980) Theoretical and applied aspects of machinery repair and maintenance, Rousse.