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ANALYTICAL - PROGNOSTIC MODEL OF THE TECHNIQUE OPERATION

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A b s t r a c t :

The article introduces a dynamical model of the technique's operation (generally). The model enables to describe reciprocal structures of basic operational phenomena, analyse progress tendencies of operational coefficients and determine prognosis of a future progress of the technique's operation.

1. Introduction

Generally a current fast progress of the special technique demands also improvement of planning methods of its operation. Depending on a type of technique, the cost exceeds two to five times of the secure operation the cost of its purchase, during its life-time,. It calls for incessant improvement of tools for its control [2]. The progress of the information systems anticipates a gradual introduction of new methods and models of processing information of the operation's processes (**see *Figure 1***). In the following part of this particle we use in general the term "technique".

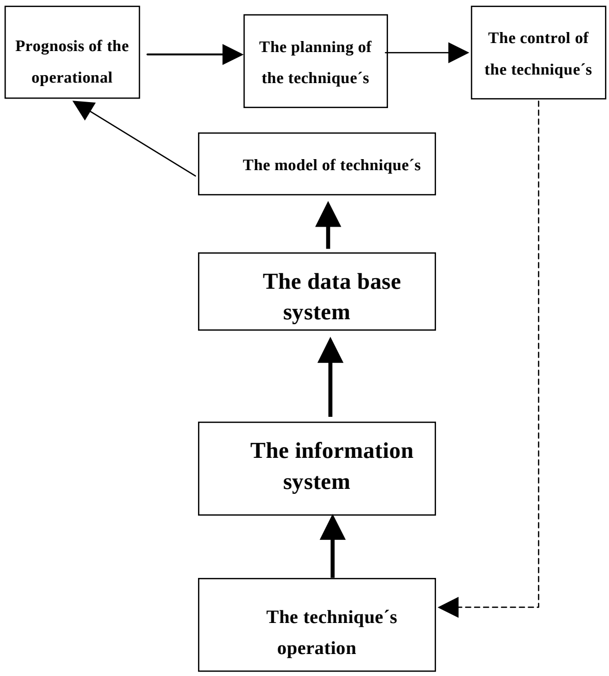


Figure 1 Diagram of the information system of the technique's operation

In the early 1990s the usage of the expert estimation of the leading managers based on their experience was sufficient for decisions regarding the planning and control of operation.

Nowadays, it is necessary to introduce more accurate and exact methods of controlling all the processes of the technique operation.

2. Model of the technique operation

A model construction of the of the technique operation is based on a study of the direct connections between the operation phenomena and their relations. These operation phenomena are performed in a real operational environment and that is why they are influenced by a variety of expected and also coincidental impacts .

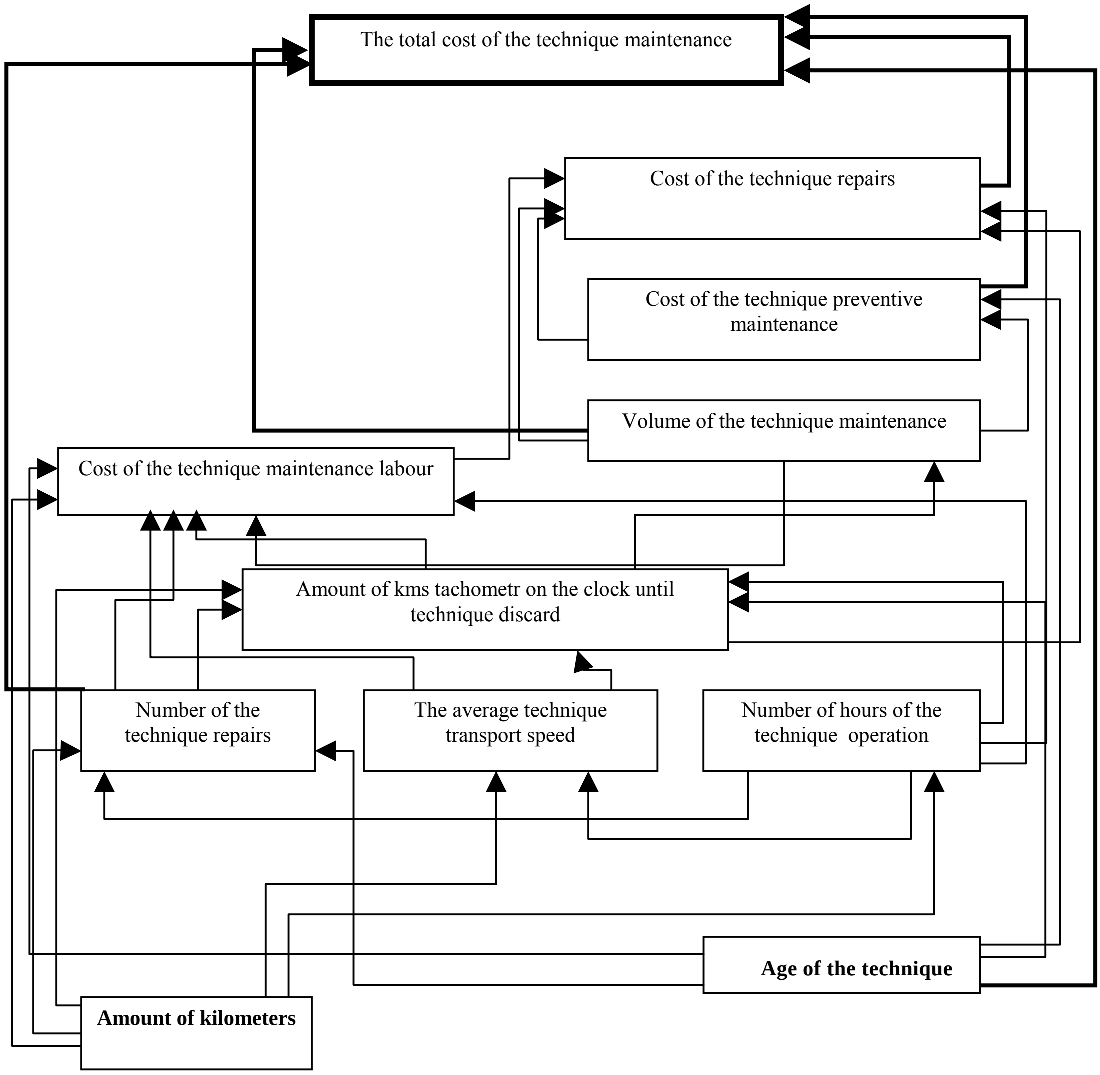


Figure 2 Diagram of the causal affinity

Because the behavior of the technique operation is determined by the relevant causal affinity among the operational coefficients, the model construction is based on the logic of proved hypotheses about the causality of the affinity among these operational coefficients. On the ***Figure 2*** there is the set-up of the causal structures among the variable values of the technique's operational system. The ***Figure 2*** illustrates the intensive hierarchy of the causal affinity among the operational coefficients. The causality is expressed by an orientated abscissa among the operational coefficients; for example, the number of repairs is influenced by the age of an equipment, number of kilometers on the clock, even the amount of operational hours etc. The starting point of the abscissa is the cause and the terminal point is the consequence of the causal structure.

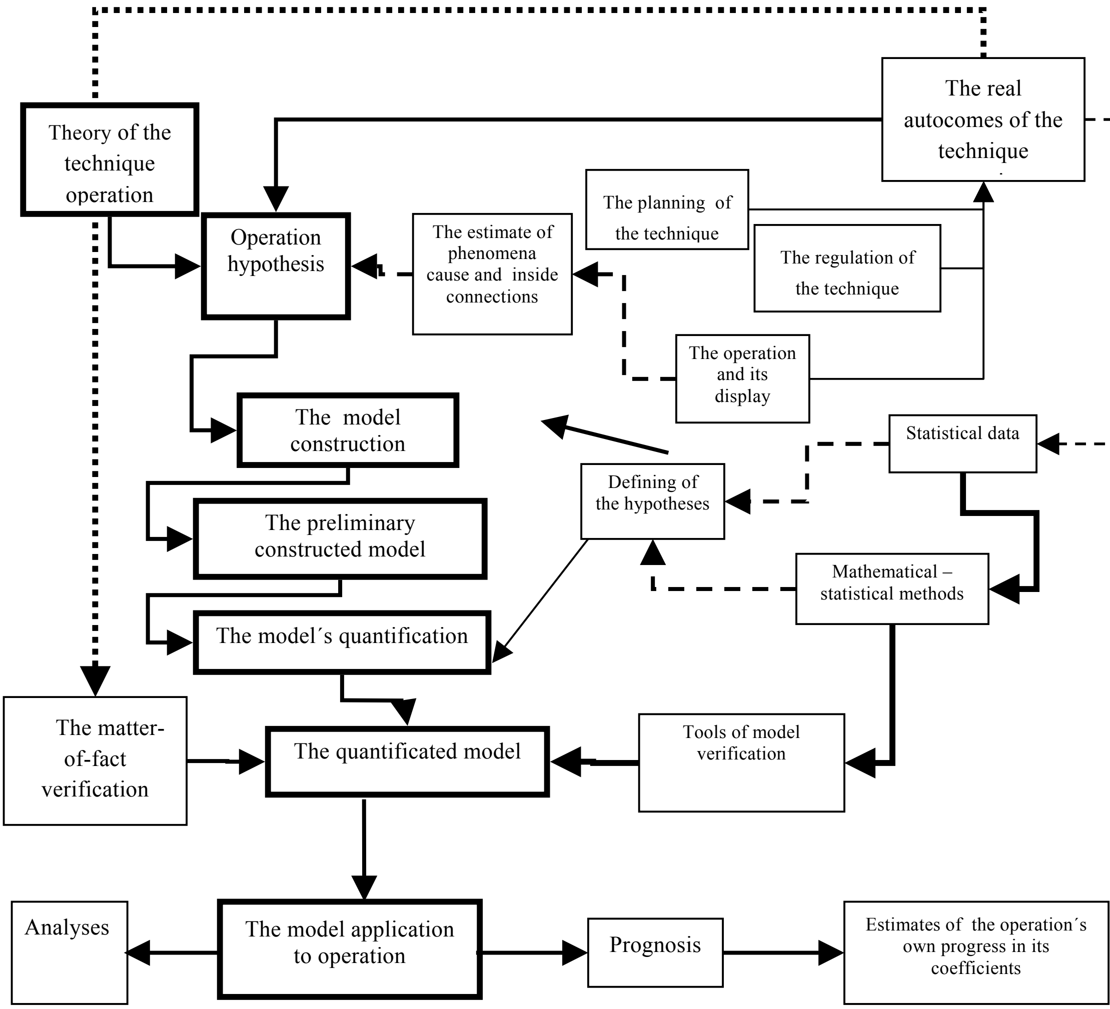


Figure 3 Diagram of the model's construction

The next step of the construction of the technique operation model (see ***Figure 3***) was to describe the operational coefficients by the linear coincidental progressive equations, each of them expresses a mechanism of a creation and progress of the single operational coefficients of the technique by the explanatory variable values.

The linear progressive equation isin this a form:

$$\boldsymbol{y}_t = a_0 + a_1.\boldsymbol{x}_{t1} + a_2.\boldsymbol{x}_{t2} + ... + a_n.\boldsymbol{x}_{tn} + \boldsymbol{e}_t \qquad (1)$$

where:

$\mathbf{y}_t$ is a vector of observation (time sequence) of explained variable value (explained operational coefficient),

$\mathbf{x}_{t1}...\mathbf{x}_{tn}$ are vectors of observation of explanatory variable values (explanatory operational coefficients),

$a_o...a_n$ are parameters of the progressive equation,

$\mathbf{e}_t$ is a vector of divergence – remainders.

The sources of the operational coefficients are chosen time sequences, which are created in the information system. The time sequences bring to the description of the technique operational coefficients the needed dimension of time, and they monitor best all the movements and changes of the technique during its operational time - from the start of its operation until it is discarded and refused.

There are following variable values in the equations No. 1 to 9 (see chapter 3) of the technique operation model (according to the information system of Transport Company):

T **- an age of the technique [month].** This variable value brings information about the aging of the technique, its aggregates and materials, which the technique is made from.

N **- number of equipments [-].** Shows the amount of equipments being operated in an observed period.

xt **- amount of kilometers on the clock [km].** Shows the volume of the technique's operation.

tj **- amount of the technique operational hours [hrs].** Shows the time when the technique was in operation.

Vavg **- average transport speed [kms / hr].** The average transport speed shows the affinity of the amount of kms on the clock and amount of the technique operational hours.

$N_{repairs}$ **- number of repairs [-].** This number shows an amount of repairs in the service place after the technique's failure.

$X_{disc.}$ **- amount of kms on the clock until the technique's discard [kms].** The amount of kms on the clock until the technique's discard is a distance, which the technique makes between two sequential times of put aside. By the put aside is meant any time off operation (for example, the driver's illness, MOT and the emissions analysis, the revision of the pressure compound etc.). This operational coefficient is important especially for a determination of the amount of the back-up technique and the cost of its maintenance.

t_{Sh} **- volume of the technique maintenance [Sh].** The volume of the technique's maintenance summarizes a volume of the labour done on the technique as a preventive and repairing maintenance in standardized hours.

$N_{labour\ in\ CZK}$ **- cost of the technique's maintenance [CZK].** An operational value which include the total cost of preventive and repairing maintenance labour, carried out in the service place as well as by the supply organizations (mounting of the special equipment, expert work of the authorized services etc.)

TO_{total} **- cost of the preventive maintenance [CZK].** Cost of the preventive maintenance is the operational value showing information of the necessary cost of technique operational preventive repairs.

BO_{labour} **- cost of the technique's repairs labour [CZK].** Cost of labour of the technique repairing maintenance is the operational value, which shows cost of repairs when the technique fails.

$CN_{repairs}$ **- overall cost of the maintenance [CZK].** Total cost of the maintenance is a very important operational value especially for the area of operational economics. It is necessary part of the operation plan. It is expressed in monetary values and shows total cost including the spare parts used during the maintenance and repairs.

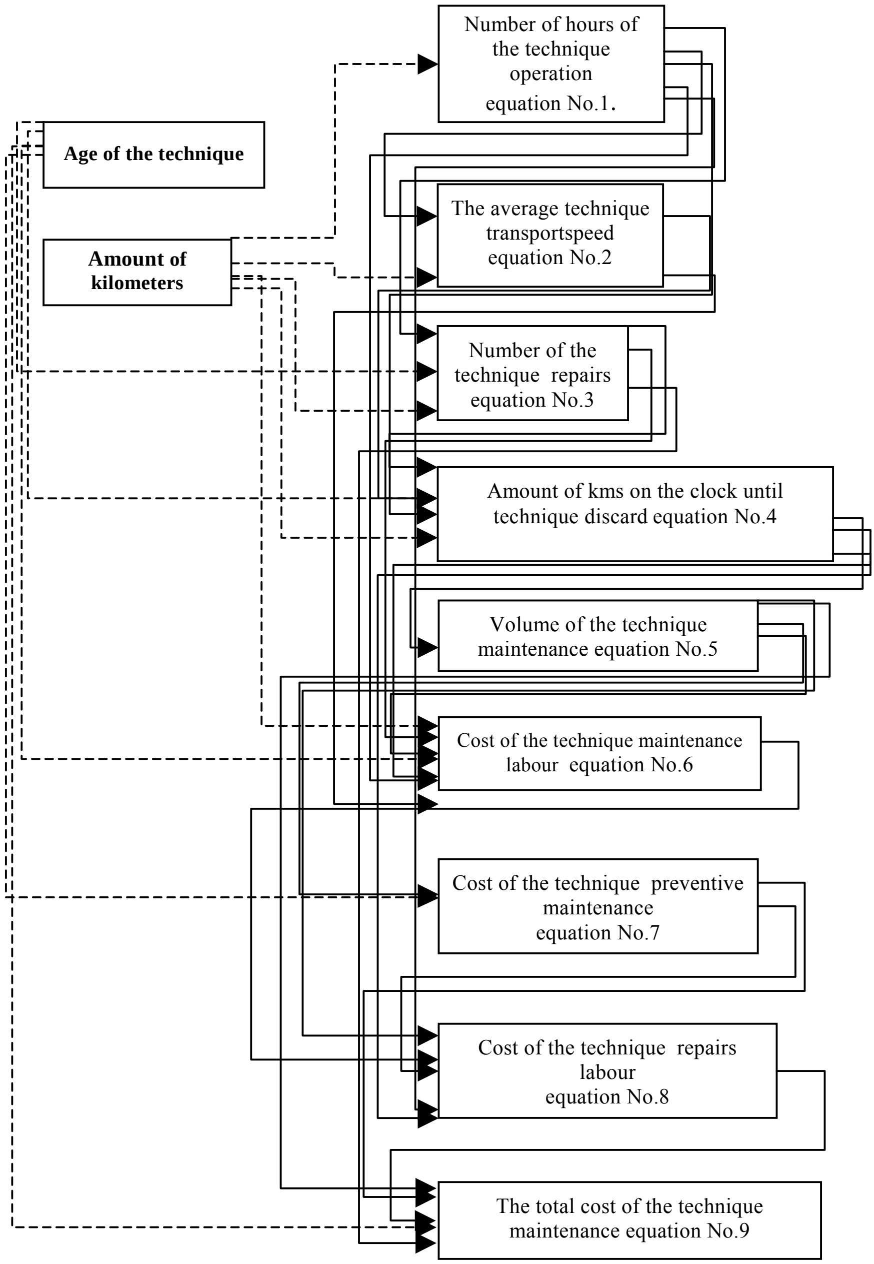


Figure 4 Diagram of the model equations compiling

The model equations are compiled in the way, that they are linked together only in one direction. Only this way of compiling the model equations enables to use the explained values in a following equation as an explanatory value (see ***Figure 4***).

Parameters of the single progressive equations, which express quantitative rates of direct influences of the explanatory variable values on a dependant variable value, are evaluated by the statistical time sequences of the different technique operational coefficients by the method of the smallest squares, according to the formula:

$$\hat{a} = (\boldsymbol{X}'.\boldsymbol{X}).\boldsymbol{X}'.\boldsymbol{y_t} \qquad (2)$$

where:

- **â** is a statistical evaluation of the explanatory values´ parameters,
- **X** is a matrix of observation of the explanatory values,
- **X´** is a transponned matrix of observation of the explanatory values,
- $(\boldsymbol{X'.X})^{-1}$ is a inverse matrix,
- $\mathbf{y_t}$ is a vector of observation of the explained operational value.

The method of the smallest squares is complemented by other testing procedures. The rate of a total explanation of the operational coefficient progress with the used variable values is evaluated according to a determinative coefficient R_2. Auto correlation of the coincidental remainders divergences are tested by the Durbin-Watson's coefficient (d). While the equations are being quantified, the emphasis is put on the reaching the highest rate of explanation of the model equations (the highest rate of the determination's coefficient).

3. Achieved results

For the model evaluation the real data of the existing operation were used - 16 pieces of technique SOR 10.5 of a transport company, which provides regular daily transport. The time sequences of operational coefficients were three months with the length of the time line 16 periods. The analyzed time sequences cover the technique operation from 2001 to 2004 which is 4 years.

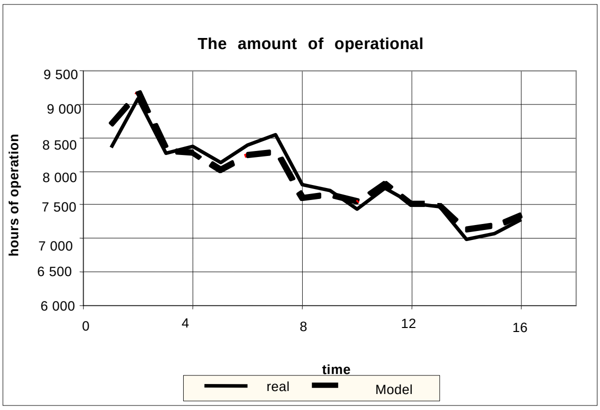
Results of the equations are following:

1. The amount of operational hours

$$t_j = 575.635998 + 0.03491 x_t$$

$R^2 = 0.974$

$d = 0.517$

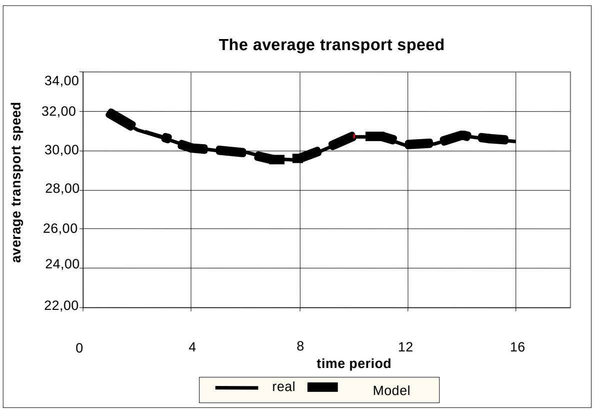


2. Average transport speed

$$v_{avg} = 30.596213 + 0.000121 x_t - 0,003704 t_j$$

$R^2 = 0,9977$

$d = 2,141$

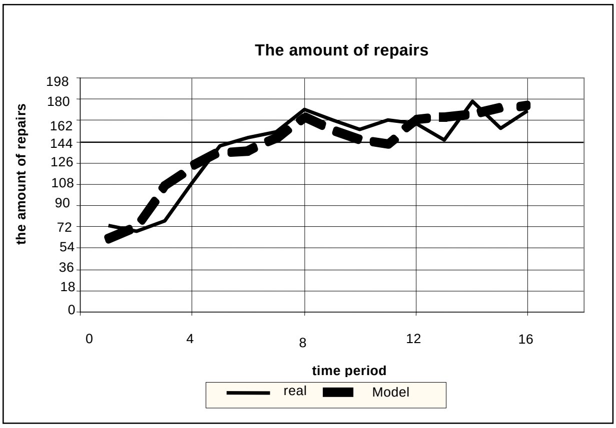


3. The amount of repairs

$$N_{repairs} = 275.55692 + 1.018195\boldsymbol{T} - 0.003647\boldsymbol{x}_t + 0,088745\boldsymbol{t}_j$$

$R^2 = 0,8207$

$d = 1,557$

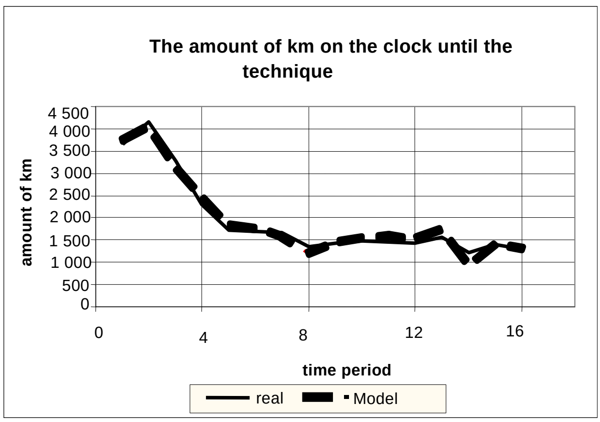


4. The amount of kms on the clock until the technique's discard

$$X_{disc} \quad 96492.865919 \quad 5.790895T \quad 0.426222x_t \quad 12.525576t_j \quad 3151.665863v_{avg} \quad 16.977148N_{repairs}$$

$R^2 = 0,9731$

$d = 1,990$

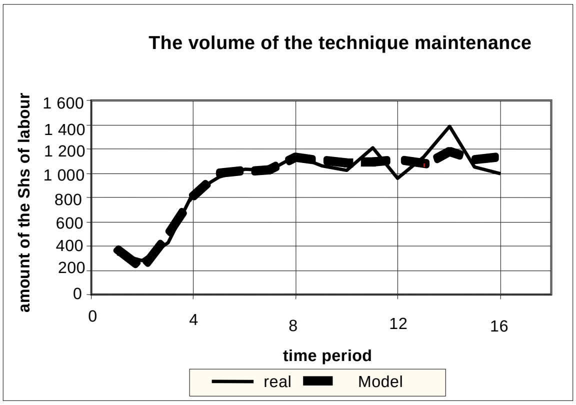


5. The volume of the technique maintenance

$$\boldsymbol{t}_{Sh} = 1564.2206 - 0.326632\boldsymbol{X}_{disc}$$

R^2 = 0,9066

d = 2,237

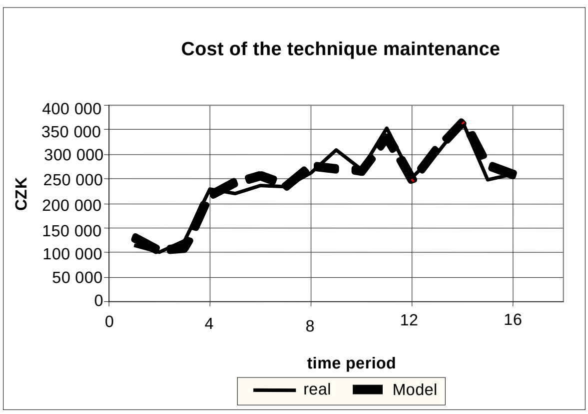


6. Cost of the technique's maintenance

$$N_{LabourinCZK} \quad 8.475386.10^6 \quad 648.089864T \quad 38.917251x_t \quad 1166.453348t_j$$
$$2.82294.10^5 V_{avg} \quad 609.587855N_{repairs} \quad 11.197729X_{disc} \quad 322.876046t_{Sh}$$

R^2 = 0,9059

d = 2,030

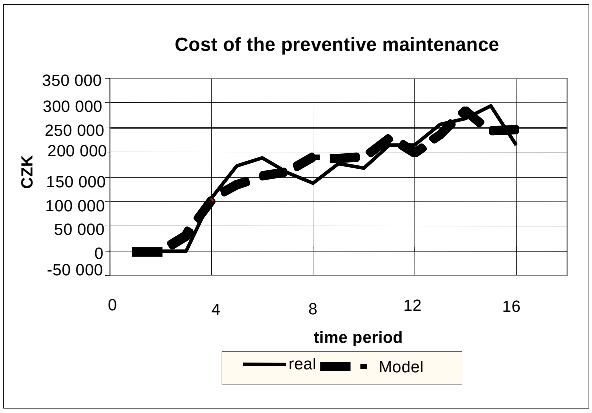


7. Cost of the preventive maintenance

$$\boldsymbol{TO}_{total} = -1.03617.10^5 + 3264.05189\boldsymbol{T} + 152.384112\boldsymbol{t}_{Sh}$$

R^2 = 0,8974

d = 1,980

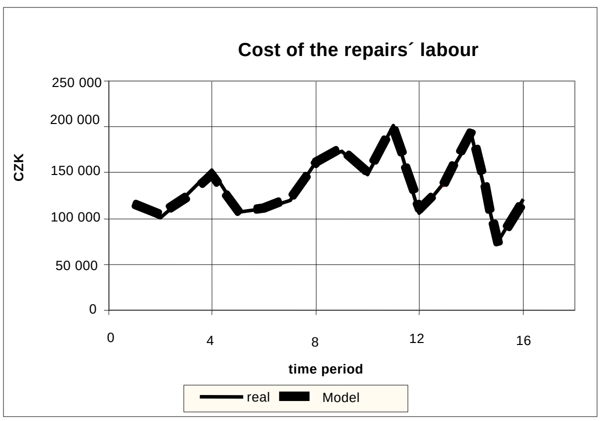


8. Cost of the repairs´ labour

$$\boldsymbol{BO}_{labour} = 23999.8474 - 9.480472\boldsymbol{t}_j + 0,77638\boldsymbol{N}_{labourinCZK} + 49.452418\boldsymbol{t}_{Sh} + 17.785647\boldsymbol{X}_{disc} - 0.524005\boldsymbol{TO}_{total}$$

R^2 = 0,9897

d = 2,407

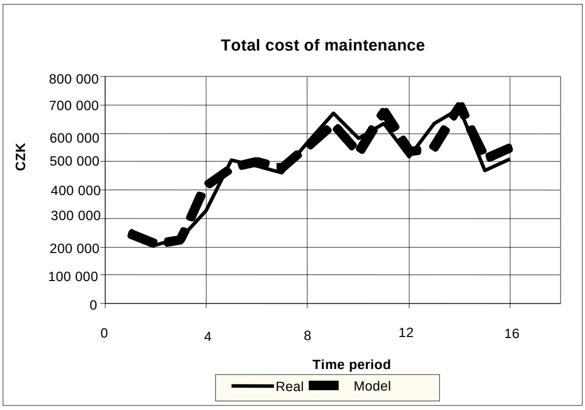


9. Total cost of maintenance

$$CN_{repairs} = -1.059455.10^5 - 4081.56212T + 1.705139TO_{total} + 2.33346BO_{labour} + 3863.07152N_{repairs} - 409.3085t_{Sh}$$

R^2 = 0,8929

d = 2,248



4. Prognostic implementations of the model

Prognosis of the main operational coefficients are the main issue and the final product of the model of the technique operation. The prognosis of the technique operation presents applications of the models equations to a future period with the use of creation mechanisms of the single operational coefficients.

The size of operation (illustrated by the covered number of kilometers) and the age of the technique are only two basic parameters, which will be during the prognostic implementations input into the model. The number of the kms will be dependant on the volume of demanded technique operation in the prognosticated period (e.g. demand for a transport service). The amount of the techniques´ number remains usually unchanged even for the future period and thus the age of the technique is possible to determine according to a simple linear time function.

The prognostic implementation of the technique operation model was used for the creation of the technique operation plan for the 1st, for the first three months of 2005. Whether the prognosis has been successful can be now determined by comparing it with the real numbers.

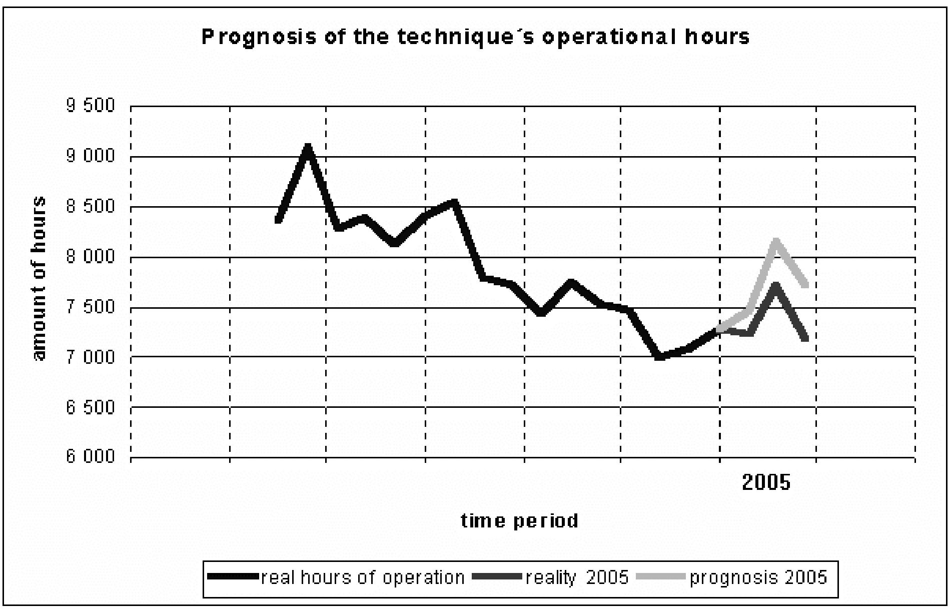
As an example of a real implementation there is the calculation of prognosis of the important operational coefficient:

- the amount of operational hours,
- the total cost of maintenance.

The prognosis of the Amount of the operational hours is an important coefficient for creating the plan of drivers´ wages expenses, service personnel and the clerks and logistic personnel's salaries.

Matrix of the amount of technique operational hours

Period of prognosis (3 mths / year)	Age of technique (months)	Amount of kms x t sk (kms)	Prognosis of the operational hours´ amount (hrs)	Real amount of the operational hours (hrs)	Divergence of prognosis from the reality (%)
1/2005	63	225997	7467	7220	**3,4**
2/2005	66	248325	8147	7706	**5,7**
3/2005	69	233789	7704	7165	**7,5**

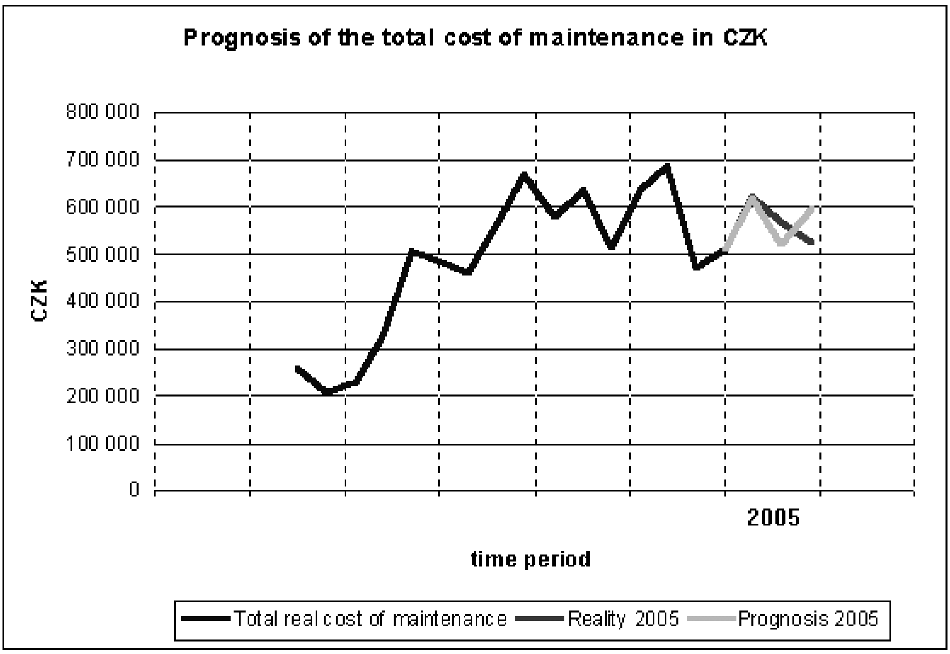


Prognosticated value "Amount of operational hours" correctly shows the progress tendency of the amount of the technique operational hours and it can be considered accurate enough (the divergence from reality is only 3,4 – 7,5 %).

Prognosis of the total cost of maintenance is a very important operational economical coefficient. It shows total cost of the secure maintenance which includes cost of the spare parts and the necessary labour of the service personnel.

Matrix of the prognosticated "Total cost of maintenance" in CZK

Period of prognosis (3 mths / year)	Age of technique (months)	Amount of kms x tsk (kms)	Prognosis of the total maintenance cost (CZK)	Real total cost of maintenance (CZK)	Divergence of prognosis from the reality (%)
1/2005	63	225997	617 688	622 236	**- 0,7**
2/2005	66	248325	519 738	567 391	**- 8,4**
3/2005	69	233789	596 374	527 149	**- 13,1**



Prognosticated value "Total cost of maintenance" in CZK correctly shows the progress tendency. It can be considered accurate enough.

5. The conclusion

Usage design model of operation technics makes possible to improve system of planning and system management of munitions and technics in AČR. Model removes inadequacies contemporary information system which give effect to only acquisition of data about operation single type of munitions and technics.

Structure of model creates operative system upgrade whereupon data bank of information system and makes possible to specify and accelerate planning process of munitions and technics and prepares credible information for determination of authorities symbolic logic.

R e f e r e n c e s

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