ACTA TECHNICA CORVINIENSIS
BULLETIN OF ENGINEERING

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DYNAMICAL MODEL OF CAPACITIVE PLANNING

Abstract:
The workers of companies form the essential part of producing systems. Especially today, the question of right number of workers is still more and more discussed. Nowadays, we are able to determine the necessary number of manufacturing workers precisely and relatively easily. The new challenge of industrial engineers it is to develop a method for sufficiently exact capacitive model in the area of indirect labour. A new approach based above all on the statistical methods and the time series forecasting will be introduced in this paper. This introduced model has been tested in the real processes of producing companies.

Keywords:
capacitive planning, indirect labour, time series forecasting, work mesuarement

INTRODUCTION

Nowadays we are able to determinate a number of human resources quite easy in a manufacturing. Human resources planning in the field of indirect labour it is next significant step at capacity planning. We are still not able to determinate the right number of machine adjusters, maintainers, technologists etc. The reason it is above all a stochastical nature of these activities. Today we use usually methods for capacity planning like:

- benchmarking [1],
- backlog management [2],
- work measurement [3],
- budget management [4],
- ratio coefficient planning [5],
- computer simulation.

These methods have sure disadvantages, that is why industrial engineers look for another suitable method. The developed dynamical capacitive model is another approach, which can provide sufficient results. [6]

SUBSTANCE OF THE DYNAMICAL CAPACITIVE MODEL

The substance of this dynamical model is descripted on the figure 1. The needed number of workers in h^{th} week is possible to count from quite simply equation (1).

$$K_h = \frac{T_h}{TF} = \frac{A}{60\ TF} \sum_{j=1}^{m} \sum_{i=1}^{N_{j,h}} t_{i,j} \qquad (1)$$

Where T_h is a total supposed required time (in minutes) for a fulfilment of all tasks in h^{th} week, TF is the week time fond of one worker, A is a time allowance, which includes occasional tasks to the computing , $t_{i,j}$ are generated durations of tasks, m is the number of main tasks, $N_{j,h}$ is the

forecast number of j-type task requirements in h^{th} week.
If we are able to term work tasks and measure durations of tasks, then we need to know only numbers of task requirements in the future. Then we are able to determinate the necessary number of workers. This is describe by equation (1).

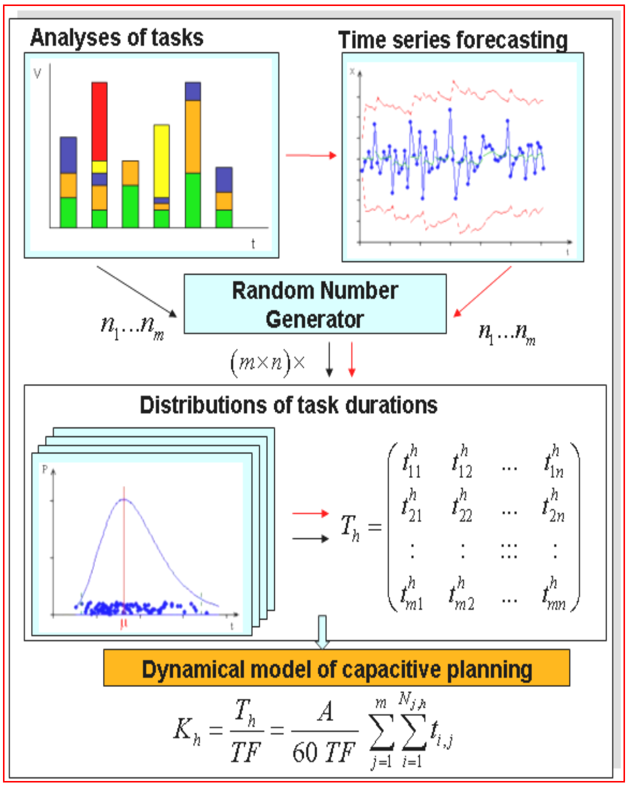

Fig. 1 Substance of the dynamical capacitive model

The needed input data for the model are obvious from the figure 1 and from the equation 1. They are:

- list of tasks,
- structure of working day and tasks ratio,
- durations of chosen tasks,
- time series of task requirements,
- time fond of one worker.

PROCESS OF DYNAMICAL CAPACITIVE MODEL APPLICATION

List of Tasks

Create a list of worker´s tasks. The list should include all the main tasks which the worker does. A base of the list can be created via interview with the worker. The rest of list will be created during recording of working day.

Structure of Activities During Working Day

Determination of working day structure is the main aim of the observation. There are usually divided activities according to value added in the area of manufacturing activities. The experience gained show that dividing according to frequency of task repetitiveness is more suitable in the area of indirect labour. The structure of working day of machine adjusters is shown on the figure 2. We can see that the main hight frequent tasks create 51% of working day, the another low frequent tasks create 11% and the waste create 38%.

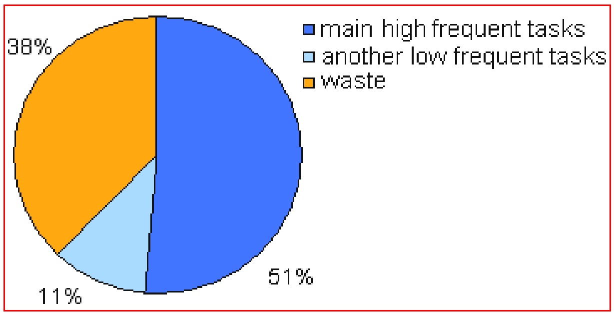

Fig. 2 Structure of Working Day

The 11% of working day which adjusters do low frequent task will be include to the capacitive model via coefficient allowance A, which is given by the equation (2).

$$A = \frac{HF + LF}{HF} \qquad (2)$$

Distributions of Main Tasks Durations

One of the basic stones of the dynamical capacitive model it is determination of distributions of main tasks durations. First we have to mesuare the durations of each main tasks. When we have enough mesuarements than the goodness of fit tests can be done. These tests will show us from witch kind of distribution an experimental data comes.
If we have more than 30 measurements and there is no empty interval in the histogram, we can use Pearson´s chi-squire test. In case we have only a few mesuarement it is suitable to use the Kolmogorov-Smirniv test. [7] These tests provide us the information if an experimental data comes from tested distribution. We will

choose the most suitable distribution according to the highest p-value.

The performed experiments shows that the task durations come usually from a normal, lognormal or multi modal distributions. The histogram of experimental mesuared durations of machine adjusting is shown on the figure 3. We can see that these durations come from the normal distribution, which is given by equation (3).

$$f_N(x)=\frac{1}{\sigma\sqrt{2\pi}}\cdot e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \qquad (3)$$

Where μ is the average duration and σ is the standard deviation.

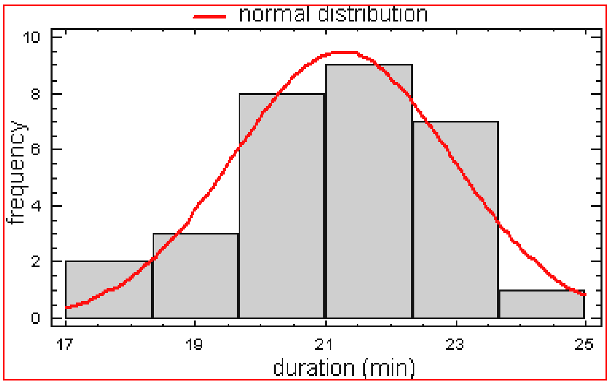

Fig. 3 Histogram of durations with normal distribution

The histogram of experimental mesuared durations of machine adjusting is shown on the figure 4. We can see that these durations come from the normal distribution, which is given by equation (4).

$$f_{LN}(x)=\frac{1}{x\sigma\sqrt{2\pi}}\cdot e^{-\frac{1}{2}\left(\frac{\ln x-\mu}{\sigma}\right)^2} \qquad (4)$$

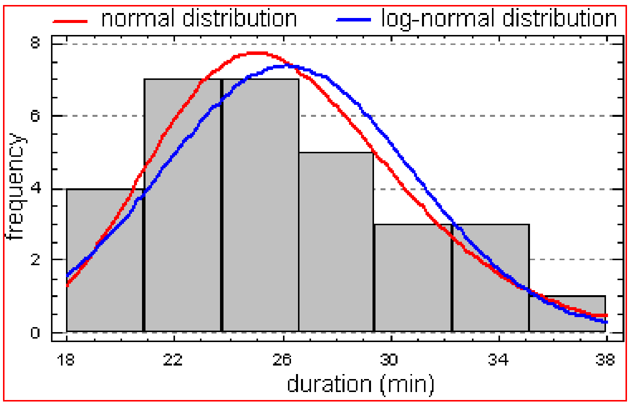

Fig. 4 Histogram of durations with lognormal distribution

The found distribution will be of serve to pseudo-random numbers generation. Now we already know with witch distribution we have to generate expected durations of mashine adjusting but we still do not know how many numbers we should generate. The required numbers of generated random numbers depend on forecast numbers of task requirements. This second basic stone of the dynamical capacitive model is introduced in the following sub chapter.

Time Series of Task Requirements and their Forecasting

This sub chapter is focused on the principles for the number determination of reguiered tasks n_i in the future. We suppose, that n_i from past are known from an information system of company. We can use common methods for analyze time series like an approximation, smoothing or seasonal decomposition. In case that the time series have variable seasons it is more suitable to use Box-Jenkins methodology.

The Box-Jenkins methodology and its complex model SARIMA is used for analyze and forecast of complicated time series with variable seasonal components. The complex model SARIMA consist of six processes. Three type of processes described the trend and three type of processes described the seasonal component of time serie. Autoregressive processes AR (p), Moving Average processes MA (q) and Integrated processes I (d) belong to processes for trend description. We can describe them by equations (5), (6) and (7). [8]

$$x_t=\varepsilon_t+\sum_{i=1}^{p}\phi_i x_{t-i}=\varepsilon_t+x_t\sum_{i=1}^{p}\left(\phi_i B^i\right)\Rightarrow\varepsilon_t=\phi_p(B)x_t \quad (5)$$

$$x_t=\varepsilon_t-\sum_{i=1}^{q}\theta_i\varepsilon_{t-i}=\varepsilon_t\left(1-\sum_{i=1}^{q}\theta_i B^i\right)=\varepsilon_t\theta_q(B) \quad (6)$$

$$\varepsilon_t=(1-B)^d x_t=\Delta^d x_t \quad (7)$$

Where the x_t are members of time series, the ε_t is residuum, the B is the lag operator, the p, q, d are integers, which mean degree of process and the ϕ_t,θ_t are the parameters of processes.

If we combine processes AR (p) and MA (q), we will obtain Autoregressive Moving Average model ARMA (p,q) for stationary time series. If *we include also I (d) process, we will obtain Autoregressive Integrated Moving Average model ARIMA (p,d,q). They are descripted by equations (8) and (9). [9]*

$$\phi_p(B)x_t = \theta_q(B)\varepsilon_t \qquad (8)$$

$$\phi_p(B)\Delta^d x_t = \theta_q(B)\varepsilon_t \qquad (9)$$

Seasonal character is included to Box-Jenkins models by seasonal processes such as Seasonal Autoregressive processes SAR (P), Seasonal Moving Average processes SMA (Q) and Seasonal Integrated processes SI (D). These processes are analogously described by equations (10), (11), (12), where P,Q,D are integers, which mean degree of process and the S is number of time units, which means seasonal character.

$$\varepsilon_t = \Phi_P(B^S)x_t \qquad (10)$$

$$x_t = \Theta_Q(B^S)\varepsilon_t \qquad (11)$$

$$\varepsilon_t = (1-B^S)^D x_t \qquad (12)$$

Complete model SARIMA (p, d, q) (P, D, Q) s is described by equation (13), where the member in the sum includes nonzero average value of the time series. [10]

$$\phi_p(B)\Phi_P(B^S)(1-B)^d(1-B^S)^D x_t = = \sum_{j=1}^{S}\delta_j^* D_{j,t} + \theta_q(B)\Theta_Q(B^S)\varepsilon_t \qquad (13)$$

The described equations show only slight part from large linear stochastical processes, Box-Jenkins methodology and all the topic of time series. These issues are explained in more details for example in the monograph [11] or on the thesis [12].

Today is usually used some of statistical software for creating time serie model and time serie forecast. Statistical software Statgraphics Centurion XV has been used for analyzing time serie of task requirements. The model with the lowest value of the Akaike Information Criterion (AIC) is model ARIMA (2,0,2) with constant. This model has been used to generate the forecasts. This chosen model ARIMA (2,0,2) with constant is shown on the figure 5.

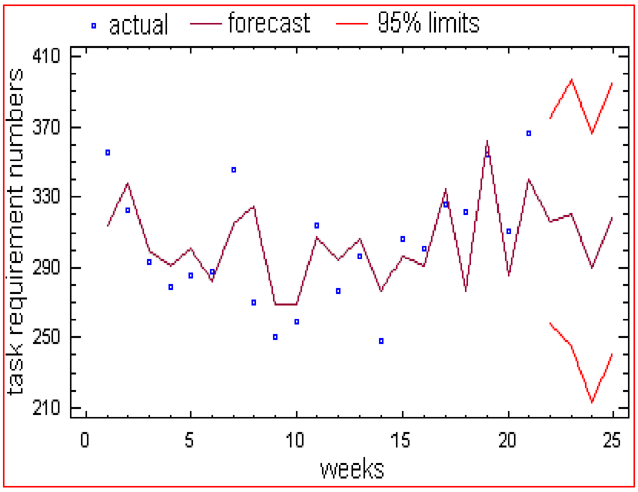

Fig. 5 The model ARIMA (2,0,2) with constant

This model show us expected numbers of adjusting in next weeks. Now we know how many pseudo-random numbers (the durations) we should let generate.

Capacitive Counting

At this moment we have all the necessary input variables for capacitive counting trough equation (1). This capacitive model has been used and verified for counting needed number of machine adjusters in one producing company. The counted number of needed adjusters is showed on the figure 6.

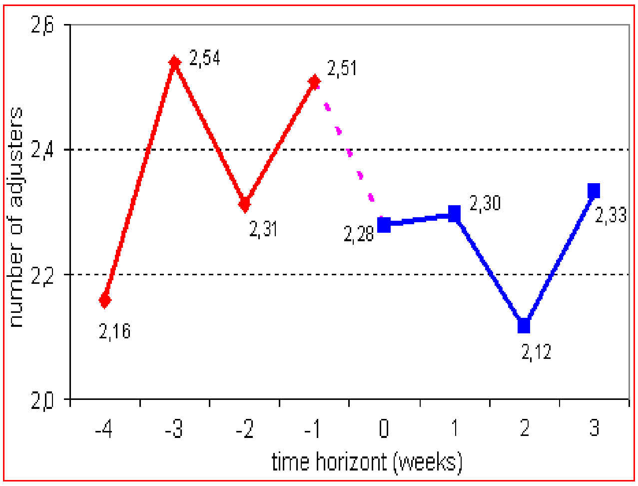

Fig. 6 Needed number of adjusters

The red points and line mark needed numbers of adjusters at the last 4 weeks. This counting comes from the real numbers and the generated expected durations of adjusting.

The blue points and line mark needed numbers of adjusters at the next 4 weeks. This counting comes from the forecast numbers and the generated expected durations of adjusting.
The results show that the necessary number of adjusters is between two and three for this case study, that means we have to count with three adjusters.
Currently, four adjusters are employed in that workshop. The group productivity of 3 (the dash polyline) and 4 (the full polyline) adjusters is shown on the picture 7.

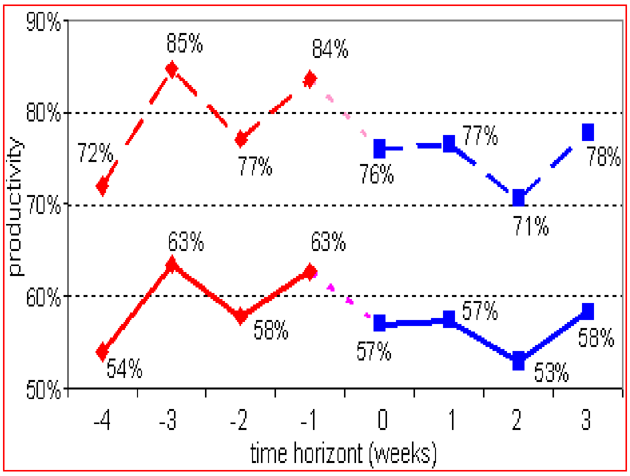

Fig. 7 Productivity of group 3 and 4 adjusters

It is obvious from the figure 7, that one of the adjusters can be moved to another workshop. The rest of three adjusters will be able to adjust all the machines with the productivity between 71% and 85% at the mentioned workshop.

CONCLUSION

The question, how many workers a company needs in a workshop, it is the high actual issue of today in the field of indirect labour. The conventional methods used originally for direct labout do not give satisfactory results above all thanks a stochastical nature of indirect labour. In the paper has been introduced the new approach to solving capacitive planning. This approach is based on usage advance statistical methods and time series forecasting. The developed dynamical capacitive model has been verified in the workshop of the producing company. The usage of this algorithm is reducing a cost about 500.000,- CZK (20.000,- €) per year to the company. The dynamical model and its algorithm will be tested also in another companies. At this time, a software for easier usage of introduced dynamical model is developed.

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Scientific supplement of
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JOURNAL of ENGINEERING
ISSN: 1584-2665 [print]
ISSN: 1584-2673 [CD-Rom]