A model for predicting the design work timing using an integrated moving average (ARIMA)

L B Zelentsov*, L D Mayilyan, D V Pirko
Don State Technical University, 1 Gagarin sq., Rostov-on-Don, 344002, Russia
E-mail: Zelentsov@rgsu.ru

Abstract. The article discusses the issues of automating the company standards’ development for labor consumption taking into account the projects’ uniqueness and the significant impact of the human factor on labor productivity, which can be indirectly measured at the stage of operational management with the pace and work intensity. In the proposed method, due to the higher frequency of information retrieval and the use of the integrated moving average model (ARIMA), at the early stage of the design work, it is possible to identify and predict their possible deviations from the planned time parameters, and then based on this, analyze and make the corrective management solutions to optimize their time parameters. This approach, combined with the leading design specialists’ expert evaluations, makes it possible to set the planned values for the complexity and duration of work, which are then specified and updated during the specific project’s implementation. The use of the methodology is considered in the context of the application for the collection and processing the large amounts of information of an intelligent design management system (IMS “Design”) developed at DSTU.

Introduction
The project activity feature is the uniqueness of the projects, and their high complexity in connection with which its effectiveness largely depends on the human factor - conscientiousness, qualifications and coordination in the work of staff and, above all, the ordinary designers.

Our proposed methodology is aimed at increasing the adaptability of the design management model, which makes it possible to control the design pace and adjust it not only to the features of a particular project and a project team, but also to the features of each designer. The task is to carry out the adjustment of the control system to the specific conditions of its implementation at an early stage of work on the project, taking into account the data of previously completed counterpart projects. This approach, combined with the expert evaluations of leading design specialists, allows to accurately set the planned values of the labor costs and work duration with their subsequent refinement and updating in the design process. The traditional approach to managing the project’s time parameters involves first calculating the work of the temporary deviation, then recalculating the network schedule (NS) in order to determine the effect of the deviation that has arisen on its completion date and only after that to make an optimization solution. The method under consideration takes into account the significant influence of the human factor on labor productivity in the design process, which can be indirectly measured with the pace and work intensity. For this, the step of “information retrieval” is set to obtain a sufficient amount of information for predicting the working time parameters. This approach makes it possible to
identify and predict their possible deviations from the planned time parameters at an early stage. Then, based on these data, conduct an analysis and make corrective management solutions first for the work parameters’ local optimization, and then, if it is impossible to completely “pay off” their temporary deviations, recalculate the NS time parameters. In the proposed methodology, the planned amount of work is taken as 100%. Information on the work status is carried out with a certain time step \( \Delta t \) in the range from 1 till 5 days. To indicate the work for which it is necessary to carry out a procedure for optimizing the time parameters, the limiting value concept of the work pace is introduced \( \tau_p^{pr} \). The limit value of the work pace is set by the PSE for the project section and is determined by the expert means. If the actual operation pace exceeds a predetermined limit value, then it is displayed as being a subject to optimization. Such a selection procedure is necessary to speed up the processing of the large amounts of information. The execution state of the work \( B_{\xi i} \) is recorded on an accrual basis

\[
B_{\xi i} = \sum_{\xi=1}^{t_i} b_{\xi i}
\]

where \( b_{\xi i} \) is the work performance on an interval \( i-1 \).

The initial (planned) time parameters of the start \( T_{\xi}^{sp} \) and completion \( T_{\xi}^{cp} \) the work are determined based on the network calculation. Let us consider the algorithm for calculating and predicting the design work time parameters (Figure 1). The planned-source \( (i = 0) \) pace of work \( \tau_{\xi 0}^{pl} \) is calculated by the formula

\[
\tau_{\xi 0}^{pl} = \frac{100}{t_{\xi}}\%
\]

where \( t_{\xi} \) is the planned work duration.

For each information retrieval date, the required work pace is calculated \( \tau_{\xi i}^{wp} \), allowing to meet the planned deadline.

\[
\tau_{\xi i}^{wp} = \frac{100-B_{\xi i}}{t_{\xi i}^{res}}
\]

where \( t_{\xi i}^{res} \) is the residual planned work duration on the information retrieval date.

\[
t_{\xi i}^{res} = T_{\xi i}^{fp} - T_{\xi i}^{r},
\]

where \( T_{\xi i}^{r} \) — is the information retrieval date, \( T_{\xi i}^{cp} \) — is the planned completion date.

The work tension \( w_{\xi i} \) for \( i \) information retrieval step is determined by the formula

\[
w_{\xi i} = b_{\xi i} - \tau_{\xi i}^{pl},
\]

if \( w_{\xi i} > 0 \) then the process tension increases, but otherwise decreases.

\[
b_{\xi i} = B_{\xi i} - B_{\xi i-1}
\]

With a decrease in tension \( w_{\xi i} < 0 \) the pace can be maintained the same, but at the same time the value \( \Delta t_{\xi i} \) by which the planned term for completion of work will be reduced should be calculated and used as a kind of time reserve, and at the exceeded \( w_{\xi i} \) limit \( w_{\xi i}^{lim} \) values \( w_{\xi i} > w_{\xi i}^{lim} \) it is necessary to calculate the possible value \( \Delta t_{\xi i} \) exceeding the planned completion date while maintaining the planned pace.
\[ \pm \Delta t_{\xi_i} = \frac{100 - B_{\xi_i}}{r_{\xi_i}} - T_{CP}, \]  

(7)

if \( \Delta t_{\xi_i} > 0 \) then the planned period may be exceeded, otherwise it is possible to reduce it.

**Figure 1.** The block diagram of the algorithm for calculating and predicting the time parameters of design work.

The final solution can be made after the procedure for predicting the completion date based on the
integrated moving average model (ARIMA) is completed. When diagnosing the possible excess of the planned completion date, there are three possible solutions:
- not to change anything and maintain the current actual design pace;
- to increase the planned work pace to a level that allows to eliminate the backlog, for example, by increasing the number of performers or by stimulating their work with higher intensity;
- to change the planned deadline for the work within the deviation limits, while maintaining the planned pace.

Taking the fact that in the above-mentioned methodology the calculation of the pace and tension is carried out according to one work into consideration, it is necessary to determine the cumulative effect on the design solution parameters (DS) of the works included in it. For this purpose, their shares in the DS labor intensity are calculated. The share value \( \xi \) of the work \( D_{\xi i} \) in DS, is determined by the formula:

\[
D_{\xi i} = \frac{q_{\xi i}}{q_{gl}} \times 100\%, \quad \xi
\]  

where, \( \bar{q}_{\xi i} \) – is the labor input \( \xi \), \( \bar{q}_{gl} \) - is the DS labor input.

Then performing DS on the \( i \) calculation stage \( B_{li} \) can be determined by the formula:

\[
B_{li} = \sum_{\xi=1}^{\xi} D_{\xi i} \times B_{\xi i}, \quad (9)
\]

where \( \sum_{\xi=1}^{\xi} D_{\xi i} = 100\% \), where \( B_{\xi i} \) is the performance of \( \xi \) work.

Further, according to DS, its actual pace and intensity can be calculated in accordance with the algorithm discussed above. Similarly, the proportion of each DS in the project section complexity is determined. The same algorithm is used to calculate the actual pace and tension of the project as a whole.

Let us consider the example of the work, the possible options for developing and making solutions on optimizing its time parameters. The source data are the planned parameters \( \xi \) work resulting from the network schedule calculation: start \( T_{\xi s} = 2 \), completion \( T_{\xi c} = 12 \), duration \( \tau_{\xi} = 12 \), the information retrieval step is taken to be one day \( \Delta i = 1 \) days Planned Pace \( \xi \) work will be \( \tau_{\xi} = 100/24 = 8.33\% \) per day, and the limit value of the pace \( \tau_{\xi} \text{lim} \) equals 10%.

On day 8 \( (T_{\xi} = 8) \) the fulfillment \( \xi \) of the following parameters was fixed: the execution status is \( B_{\xi i} = 62\% \), the actual pace is \( \tau_{\xi} = 4.3 \). In this case, the required pace will be \( \tau_{\xi}^\text{req} = 7.6\% \), and the tension \( w_{\xi i} = 7.6\% - 4.3\% = 3.3\% \) (Figure 2).

In this situation, on the 8th day of designing, three options for making a managerial solution are possible:
- to keep existing - the actual pace until the work completion;
- to prolong the work term;
- to increase the planned pace of the work to a level that makes it possible to eliminate the backlog, for example, by increasing the number of performers or by stimulating them to work with higher intensity.
Figure 2. Graphs of changes in the work pace on the day 8 of design

Modeling of the work pace possible future values according to the option 1 showed that, while maintaining the existing pace, an increase in the tension level will be observed and the termination date deviation from the planned value will be $\Delta t_{\delta t} = 3$ days. (see Figure 5).

In case of solution 2, the planned termination date for 8 days was changed from 12 to 14 days, and the planned rate of work was increased to 9% (Figure 6).

Figure 3. Diagram of the design process intensity

With the option 3, the planned work pace was increased to 12%, which would be able to eliminate the backlog and meet the planned time (Figure 4).
Summary
To predict the design work timing, we used the integrated moving average model (ARIMA). The choice
of model was due to the fact that the schedule for changing the work pace is a time series.
A time series is a sequence of numbers (measurements) of an economic or business process in time. Its elements are measured at successive times, usually at the regular intervals.
Based on this, we can predict the future values of the time series using the models. To build them, it is best to use the autoregressive integrated moving average model (ARIMA).
Autoregressive and moving average (ARMA) models are built based on the stationarity condition. The stationarity condition for ARMA models is related to the idea underlying the linear filter model on which ARMA is based: the time series is considered to be generated under the influence of a number of independent random errors (noise, shocks) having a certain fixed distribution (usually normal). According to this idea, random shocks pass through a filter (the role of which is the ARMA model), at the output of which the values of the series \( y_t \) are obtained. Such a model works well for modeling the technical processes, but the socio-economic processes are certainly much more diverse, and therefore non-stationarity in them is much more common.
To bring the series to a stationary one, we build a model based on the differences of the value \( d \) for the subsequent periods. The autoregression model with a moving average, based on the differences, is denoted as ARIMA \((p, d, q)\) where the letter I is responsible for the integration \( d \) order (taken difference).

\[
\Delta^d Y_t = c + \sum_{i=1}^{p} a_i \Delta^d Y_{t-i} + \sum_{i=1}^{q} b_i \xi_{t-i} + \varepsilon_t
\]

\( \Delta^d \) denotes the time series difference operator of the \( d \) order. Typically, when constructing an ARIMA model, the order of differences is limited to \( d = 2 \). This is due to the fact that taking the second differences usually makes it possible to bring to the stationary form almost to any non-stationary data series.

\[
\Delta^d Y_t = c + \sum_{\xi=1}^{p} a_\xi \Delta^d \xi_{t-\xi} + \sum_{\xi=1}^{q} b_\xi \xi_{t}^{p_\xi} + \varepsilon_t
\]

In accordance with the above-mentioned algorithm for calculating the work parameters, we have developed the software that would allow to simulate various options for the development and adoption of managerial solutions in the process of the project’s time parameters optimizing locally or as a software module of the IMS “Design”.

Figure 4. Diagram of the design process intensity
References
[1] Tsypkin Y Z 1968 *Adaptation and learning in automatic systems* (Moscow, Nauka).
[2] Zagoruiko N G 1999 *Applied methods of data and knowledge analysis* (Novosibirsk, Sobolev Institute of mathematics).
[3] Karpov L E, Yudin V N 2006 Data mining techniques in constructing local metrics in the systems output case *the ISP 18*.
[4] Skurihin V I, Makarov V A, Kopytenko Y V 1984 *Designing systems for adaptive management* (Kharkov, Vyscha SHKOLA).
[5] Zhdanov A A 1999 *the Method of Autonomous adaptive control* proceedings of the Academy of Sciences. Theory and control systems 5.
[6] Gontareva I V, Nemchinov M A, Popova A D 1975 *Mathematics and Cybernetics in the economy* (Economics, Moscow).
[7] Alan Bundy 1997 *Artificial Intelligence Techniques*, Springer Verlag.
[8] Klaus-Dieter Althof, Eric Auriol, Ralph Barlette, and Michel Manago 1995 A Review of Industrial Case-Based Reasoning Tools, AI Intelligence.
[9] Anand S S, Hughes J G, Bell D A and Hamilton P 1999 "Utilising Censored Neighbours in Prognostication, Workshop on Prognostic Models in Medicine", Eds. Ameen Abu-Hanna and Peter Lucas, Aalborg (AIMDM'99), Denmark, pp. 15-20.
[10] Zelentsov L B, Ivanova N N, Sevian I K 2013 *quality Management as success factor of enterprise in competitive fight* Engineering journal of the Don 27 (4).
[11] Ayvazyan S A 2010 *Methods of econometrics: a textbook* (Master: INFRA-M, Moscow).