Modelling the reliability of the implementation of the schedule building work

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Abstract. The main issue of the study is the analysis of the impact of the level of information security of the construction process and the impact of the level of professional competence of personnel on the reliability characteristics of the planned terms of construction work. The aim of the study was to construct a simulation model and conduct simulation cycles/experiments in order to obtain the probabilistic characteristics of the output parameters, which are the possible terms of construction and the probability of implementation of these terms. Also, the aim of the study was to determine the permissible level of professional competence of personnel and the permissible level of non-availability of primary information necessary for construction work.

Results. Methods of computational mathematics in the Excel software environment built a simulation model of the construction process, which includes the sequential execution of several stages of construction work, taking into account the level of information uncertainty and probabilistic level of competence of personnel. Numerous graphical information of the change of construction terms under the influence of probabilistic factors is given. Conclusions: the Model has shown the possibility of controlling the probability vector of the construction process, and the ability to bring its output probability characteristics to acceptable deviations from the planned value.

1. Introduction

Any construction process is a complex system and is located in the following coordinate system: normative components and stochastic/probabilistic components. This coordinate system includes both the control loop of construction processes and the competence of the personnel. [1-5]

The contour of the control system of construction processes consists of a complex set of tasks of accounting, analysis, forecasting, decision-making, control of execution of decisions, control of efficiency/effectiveness of control decisions, selection of corrective control actions [6-10]. Of course, everyone understands that the information may be incomplete, inaccurate and unreliable, the methods of analysis may not be systematic, and when planning, it is impossible to take into account all the risks associated with the elements of the construction process. All this suggests that the control system circuit contains elements of uncertainty, and therefore all management decisions made in the construction sector are classified as “decisions in the field of risk and with a certain level of risk”. [11-15]
Through acquired knowledge and gained practical experience, sets of professional competencies of personnel are formed, which are characterized by certain quantitative and qualitative indicators. The competencies of the staff are also in the normative and stochastic/probabilistic coordinate system, since qualification and practical characteristics of the personnel always have a discrepancy with a plus or minus sign, also the competence of construction divisions are a function of quantitative and qualitative characteristics from the totality of employees in these units (staffing and turnover, illness and absenteeism, downtime resulting from lack of proper experience, combining professions, motivation, emotional state, constructive or destructive attitude to work, among others) [16-19].

By definition, if the parameters of the system elements include probabilistic characteristics, then the output function of the whole system also has probabilistic characteristics. It is possible to find probabilistic characteristics (expectation, variance, distribution law) of output parameters of a complex system (construction process) only by the method of simulation modeling, which is widely used not only in construction [3-7], but also in other spheres of life [11-15].

2. Materials and Methods
The simulation model utilizes an algorithm that allows to obtain probabilistic characteristics of the output parameters. This is achieved by:
1) the presence in the simulation model of sensors/generators of random numbers with certain laws of distribution: uniform, normal, Weibull, exponential, among others;
2) a certain number of runs/simulations of the functioning of the constructed model of the system under study, which allows to create an array of statistical data;
3) as a result of N number of simulations we get N number of output values, which are statistics of final results and which are processed by methods of mathematical statistics.

Table 1. Characteristics of types of construction works.

|   | Types of construction works | Work 1 | Work 1 | Work 1 | Work 1 |
|---|-----------------------------|--------|--------|--------|--------|
| 2 | Duration (T)                | T1     | T2     | T3     | T4     |
| 3 | Level of information uncertainty (IN=0-1) | IN 1 | IN 2 | IN 3 | IN 4 |
| 4 | The competence of the staff (CP= 0-1) | CP 1 | CP 2 | CP 3 | CP 4 |

The model used a sensor/generator of uniform random numbers, the number of simulation runs was equal to thirty iterations. The input parameters of the model are:
1) Four types of work, each of which was characterized by: a) its duration; b) the level of information uncertainty; C) the level of competence of the personnel performing this work;
2) the analytical relationship between the level of information uncertainty and the timing of the increase in construction;
3) the analytical relationship between the level of competence of personnel and the duration of construction;
4) the sensor is a uniform random number;
5) the number of simulation runs of the construction process model.

3. Results and Discussions
The output parameters of the model are:
1) indicators of the histogram of possible construction periods at different values of the level of information uncertainty and staff competence (Fig.1; Fig.2).
2) schedules of deviation of actual terms of construction from planned terms of construction at various values of level of information uncertainty and competence of the personnel (Fig.3; Fig.4).
3) the obtained analytical dependence of possible construction terms on the levels of information uncertainty (x) and staff competence (y) (x/y) (Fig.5).
4) Probabilistic characteristics of construction terms depending on levels of information uncertainty (x) and competence of personnel (y) (x/y) (Fig.6).
5) indicators of expectation and standard deviation, both by type of work and construction in general.

![Figure 1. Histogram of possible construction dates.](image1)
(level of information uncertainty =0.55 and staff competence = 0.65)

![Figure 2. Histogram of possible construction dates.](image2)
(level of information uncertainty = 0.2 and competence of staff = 0.8)

As can be seen from Figure 1, the level of uncertainty =0.55 and the competence of personnel = 0.65: probability of completion for the 51 period equal to 0.1 (P=0.1); the probability of completion for 39 periods equal to 0.37 (P=0.37); the probability of completion for a planned 19 periods = 0.0 (P=0.0).
Figure 2 shows the output at the level of information uncertainty = 0.2 and staff competence = 0.8; the probability of completion of construction for 23 periods is 0.73 ($P = 0.73$); the probability of completion for the planned 19 periods is 0.17 ($P = 0.17$), which is clearly not enough.

![Figure 2](image.png)

*Figure 2. The output at the level of information uncertainty = 0.2 and staff competence = 0.8.*

Figure 3 and Figure 4 show graphs of the construction process implementation with different input values of information uncertainty and personnel competence. When you change the input values, the graphs automatically (as well as histograms) change their configuration, which allows you to immediately visualize the results of modeling.

![Figure 3](image.png)

*Figure 3. Normative / planned and actual construction schedule. (when information uncertainty = 0.55 and the competence of personnel = 0.65)*

![Figure 4](image.png)

*Figure 4. Normative / planned and actual construction schedule. (with information uncertainty = 0.2 and staff competence = 0.8)*
Figure 5. Possible construction time depending on the levels of information uncertainty \((x)\) and staff competence \((y)\) \((x/y)\).

Figure 6. Probabilistic characteristics of construction terms depending on levels of information uncertainty \((x)\) and competence of personnel \((y)\) \((x/y)\).

Figure 5 shows the analytical relationship between the levels of information uncertainty and competence of personnel-on the one hand, and the possible timing of construction - on the other hand. As can be seen from Figure 5, the increase in uncertainty and decrease in competence leads to an increase in the interval of permissible deviations of construction terms.
Figure 6 shows the probability of completion of construction in a certain period of time, obtained as a result of modeling, with certain values of the level of information uncertainty and personnel competence. So, the term of completion of construction for 22 periods, corresponds to the probability of \( P = 0.77 \), and the probability to meet the planned deadlines is equal to \( P = 0.23 \). Under other conditions of information uncertainty and competence of personnel, there is the greatest probability \( (P=0.37) \) of completion of construction is 39 periods, instead of 19 planned periods.

A simulation model of the construction process was built, the main characteristics of which are presented in Table 1. The result is estimated by the indicator of the effectiveness of the decisions taken: the deviation of the actual terms of construction from the planned terms.

4. Conclusion

Based on the experiments carried out on the simulation model of the construction process [20-23] and processing of the results obtained, the following conclusions can be drawn:

1. The concepts of “information uncertainty” and “level of professional competence” used in the proposed model are integral indicators, i.e. the proposed simulation model is built on the concept of deduction (i.e., “General to particular”), which allows to further complicate it by including new conceptual categories in the simulation model.

2. The dynamics of deviations in the terms of the construction process increases faster than the dynamics of changes in the level of information uncertainty and the level of competence (see Fig.5), this suggests that the lack of competencies leads to an accelerated loss of manageability of the construction process.

3. Simulation allows you to quickly and fairly inexpensively obtain statistically significant information on all elements of the construction process, after statistical processing of which, you can make significant management decisions to stabilize the construction process.

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