Formalization of risk management in the context of digital business transformation

Koshekov Kairat[1], Alibekkyzy Karlygash[2], Toiganbayev Beglan[1], Belginova Saule[3], Keribayeva Talshyn[1], Tulaev Viktor[4], Koshekov Abai[1]

[1]Department of Aviation Equipment and Technology, Civil Aviation Academy, Almaty, Kazakhstan
[2]School of Information Technology and Intelligent Systems, D. Serikbayev East Kazakhstan Technical University, Ust-Kamenogorsk, Kazakhstan
[3]Department of Information Technology, University Turan, Almaty, Kazakhstan
[4]Theory and Methodology of Physical and Military Education, Manash Kozybayev North Kazakhstan University, Petropavlovsk, Kazakhstan

Article Info

Article history:

Received Jan 11, 2023
Revised Jan 14, 2023
Accepted Jan 19, 2023

Keywords:

Aviation industry
Decision-making
Digital transformation
Model
Probability
Technology
Transformation

ABSTRACT

The aim of the article is to develop a formal methodology for quantitative assessment of the quality of acontrol in a closed system with feedback in the context of digital transformation. In the proposed study, attention is focused on assessing the quality of management in organizational and technical systems on the example of the aviation industry. The following hypotheses were adopted in the study: in the digital management of business processes of an economic entity, the role of intellectual support is acquired by methods of formal description of processes: control, decision-making and corrective action on the control object. In critical situations, the psychotype of the person making the decision acquires a decisive role. The study solves two scientific and practical problems: development of a formal method for quantitative assessment of the quality of management of a complex multi-criteria organizational and technical system under the conditions of statistical uncertainty of management agents, taking into account feedback in the management of an object; formalization of the process of quantitative assessment of decision-making risks in the environment of statistical uncertainty of control agents and psychological factors of the decision maker.

Corresponding Author:

Alibekkyzy Karlygash
School of Information Technology and Intelligent Systems
D. Serikbayev East KazakhstanTechnical University
070004 Ust-Kamenogorsk, Kazakhstan
Email: karlygash.eleusizova@gmail.com

1. INTRODUCTION

To achieve the goal, it is proposed to solve by improving the information and analytical support of the management system. In the proposed study, two scientific and practical tasks are solved: the development of a formal method for quantitative assessment of the quality of management of a complex multi-criteria organizational and technical system under the conditions of statistical uncertainty of management agents, taking into account feedback in the management of an object. Formalization of the process of quantitative assessment of decision-making risks in the environment of statistical uncertainty of control agents and psychological factors of the decision maker.

One of the current and dominant hypotheses proposed in this study is based on the paradigm that the quality of decision-making is a systemic convergence of heterogeneous processes, where the psychological type of the person making the decision plays a decisive role. At the heart of almost every management decision there is a so-called "human factor". Herbert Simon with co-authors on this subject considers: “the choice that an individual makes in a given situation consists of his skills, knowledge, character and personality traits in the form in which they were formed by all previous life experience, and from specific influences, to which he is exposed at the time of the decision. In most cases, the former is much more important in determining his behavior than the latter” [1].

At present, in connection with the adoption of a new version of the ISO 2015 standard, which includes a regulation - to assess the quantitative value of decision-making risks in the form of "producer risk" and "consumer risk". To achieve this goal, a special supplement to the standard has been developed: IEC 31010 “Risk Management. Practices in the field of risk assessment” [2]. The decisive difference of ISO 9001:2015 compared to previous versions of ISO should be considered that “risks are no longer hidden in the standard; risk assessment is now built into the management system and becomes its integral property”. Quantitative risk assessment in the management system is fundamentally possible only by formal methods and tools.

2. FORMAL METHOD AND RISK ASSESSMENT MODELS

In the classical and modern science of digital management, it is believed that the management system is based on four functions: organization, planning, motivation, and control. In many studies, control is considered locally in an open system without taking into account feedback [3], [4]. The influence of feedback on the quality of the control process, and its impact on the system, was first considered. Closed systems are used in practice to accurately achieve the control goal [5], [6]. Control is present to varying degrees in all management functions but is often singled out as a separate organizational or technological system agent.

In this paper, the main attention is focused on the control function, which in the structural interpretation can be represented as in Figure 1. This figure shows a graphical model of a control system with feedback, which implements the restoration of the normative functional qualities of an object based on the results of control. The following notation is given in the figure: F(x) – information under study; f(s) – controlled information; S_{meas} – measured information; $Z(S_{meas})$ is a function of corrective action on the object (process) of control. As follows from Figure 1, the control of the system dynamics of an object, on a conditional universal example, is a multi-agent composition. Similar models for controlling the functional stability of a technical system are considered in works [7]-[9].

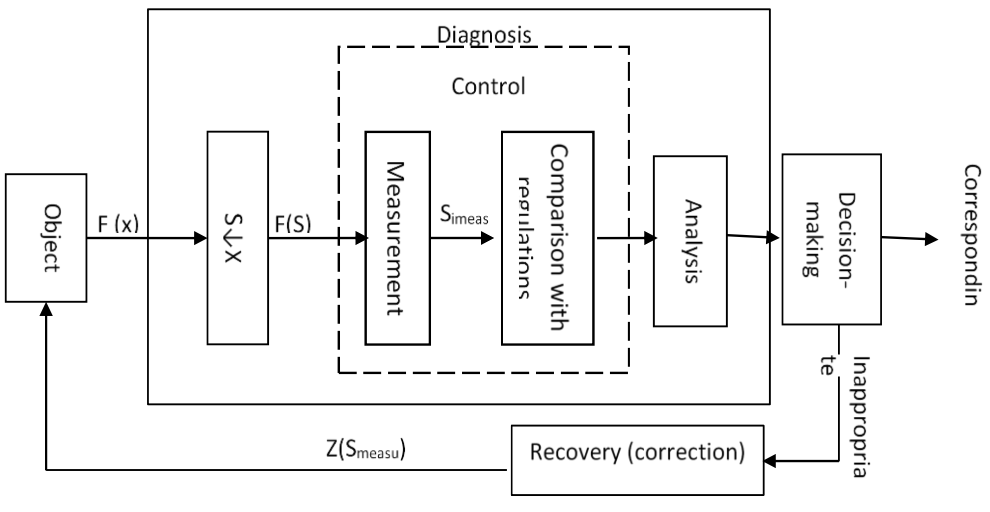

Figure 1. Agent-based model for managing the functional stability of an organizational and technical system

The control system contains, as follows from Figure 1, the function of controlling a certain flow of information F(x). The set of functional parameters F(x) at the input of the control system has a natural physical nature. In a real situation, it is not always possible to measure the selected physical parameters in existing units of measurement, and then they resort to replacing them with indirect ones, informationally correlated with physical parameters, which are called diagnostic S. In Figure 1, the set {Si} is a set of diagnostic parameters, and f(s) is a function of the distribution density of some conditional diagnostic parameter. As follows from Figure 1, the process of managing the organizational and technical system consists of the following sequence:

measurement - comparison of the measured value with the standard - analysis of the result - decision making. In most of the known works, this is the end of the control process [10]. At the same time, the main attention was focused on the quantitative assessment of control errors (control risks), which were functions of the statistical properties and characteristics of the above agents of the control system [11]-[16].

Statistical properties were hypothetically understood as distribution laws and three laws were studied: the normal law of distribution of a random variable (Gauss' law), the Weibull law, and the equiprobable law. Probabilistic and simulation models were proposed for quantitative assessment and forecasting of control risks. Thus, Makenov *et al.* [11], Kornev *et al.* [12] the issues of the software for the diagnostic process were studied in order to assess the influence of various factors on the result of diagnosis, especially on control errors, which are considered control risks. The influence of statistical laws of distribution of diagnostic parameters on probable errors of diagnosis was studied. At the same time, different initial hypotheses and statistical conditions are proposed in all studies. Probabilistic models are presented for estimating control errors with a lower limit of the controlled parameter, which have the following form:

$$P_{ff} = \sum_{t=1}^{n} \frac{1}{\sqrt{2\pi}} \int_{t_i}^{t_{i+1}} e^{-\frac{t^2}{2}} \mathrm{d}t \cdot \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z_i} e^{-\frac{z^2}{2}} dz$$

$$P_{uf} = \sum_{t=1}^{n} \frac{1}{\sqrt{2\pi}} \int_{t_i}^{t_{i+1}} e^{-\frac{t^2}{2}} dt \cdot \frac{1}{\sqrt{2\pi}} \int_{z_i}^{+\infty} e^{-\frac{z^2}{2}} dz$$

where, the probability of an undetected failure is P_{uf}, and the probability of a false failure is – P_{ff}.

An undetected failure is considered to be the case when the controlled parameter is outside the permissible limits, and the control system registers this fact as the parameter being in the tolerance zone. And vice versa, when the controlled parameter is outside the tolerance zone, and the control system registers this fact as the parameter being in the tolerance zone. The above models use the hypothesis that the statistical laws of distribution of all model parameters belong to the Gaussian law.

Alibekkyzy *et al.* [7], Kornev *et al.* [12] the hypothesis of the distribution of a diagnostic parameter according to the Weibull law, and other parameters according to the Gauss law, is studied. Using the integral function of the Weibull law, an expression was obtained in the final form for calculating the probabilities of a false failure – R_{ff}, and the probability of an undetected failure - P_{uf}.

$$\mathrm{P_{ff}} = \sum_{i=1}^{k} \left(e^{-\frac{S_i^\beta}{\alpha}} - e^{-\frac{S_{i+1}^\beta}{\alpha}} \right) \times \left[\frac{1}{\sigma_y \sqrt{2\pi}} \int_{S_H}^{S_i - 3\sigma_y} e^{\frac{y^2}{2}} \mathrm{dy} + \frac{1}{\sigma_y \sqrt{2\pi}} \int_{S_B}^{S_i + 3\sigma_y} e^{-\frac{y^2}{2}} \mathrm{dy} \right]$$

$$\mathrm{P_{uf}} = \sum_{i=1}^{k} \left(e^{-\frac{S_i^\beta}{\alpha}} e^{-\frac{S_{i+1}^\beta}{\alpha}} \right) \frac{1}{\sigma_y \sqrt{2\pi}} \int_{S_H}^{S_i - 3\sigma_y} e^{-\frac{y^2}{2\sigma_y^2}} \mathrm{dy} \sum_{i=1}^{k} \left(e^{-\frac{S_i^\beta}{\alpha}} e^{-\frac{S_{i+1}^\beta}{\alpha}} \right) \mathrm{x} \frac{1}{\sigma_y \sqrt{2\pi}} \int_{S_B}^{S_i + 3\sigma_y} e^{-\frac{y^2}{2\sigma_y^2}} \mathrm{dy}$$

Yesmagambetova *et al.* [16], the hypothesis of non-deterministic norms is studied. The standards are designated as: S_l - lower standard and S_u - upper standard and their statistical characteristics in the form of distribution laws,

$$\theta_1(S_l) = \frac{1}{\sqrt{2\pi}\sigma_l} e^{-\frac{(S_l - S_{l\,av})^2}{2\sigma_l^2}}; \qquad \theta_2(S_u) = \frac{1}{\sqrt{2\pi}\sigma_u} e^{-\frac{(S_u - S_{u\,av})^2}{2\sigma_u^2}}$$

to study this hypothesis, a simulation approach was used, and a computer experiment was implemented.

The given examples realize only particular cases of the system composition of the initial conditions of the simulation. Radjabov [8], a study was conducted to identify the total number of possible hypothetical combinations of the initial conditions for modeling. As a result, the following table was built:

In Table 1, as an example, only a part of the variant combinations is given, both between agents and the statistical distribution laws of the parameters of control agents. The total number of all possible compositions of control agents and statistical laws for only one controlled indicator, as the calculation shows, will be 729 combinations. Each combination of distribution laws is described by a specific mathematical or simulation model. The choice of distribution laws is determined by a specific practical task and are determined experimentally.

Table 1. Possible combinations of distribution laws for the initial conditions of the control system [8]

Laws $Z(S_{measu})$		Laws of psychotypes			Standards			Laws of distribution of norms			Laws of distribution f(s)			The distribution law of errors		
l	t	l	t	r	l	t	d	l	t	r	l	t	r	l	t	r
+		+			+			+			+			+		
								+			+				+	
								+			+					+
								+				+		+		
								+				+			+	
								+				+				+
								+					+	+		
								+					+		+	
								+					+			+
									+		+			+		
									+		+				+	
									+		+					+
									+			+		+		
									+			+			+	
									+			+				+
									+				+	+		
									+				+		+	
									+	+	+		+			+

Modeling of flight processes and control of complex dynamic objects is considered in [17]. But in this paper, the possibilities of using well-known universal modeling tools, such as Simscape MultibodyTM, are explored. The use of statistical approaches for modeling nonlinear systems and processes is proposed in [18], where the main tool is correlation analysis. However, the correlation coefficients of 0.9999 show that the studied variants are of a deterministic nature. In these works, it is noted that in the conditions of digital transformation of real digital models of dynamic objects, mathematical and simulation approaches for managing control risks are the intellectual support for control processes. The multiparametric nature and industry-specific requirements for business process quality management systems in the digital transformation environment in relation to the aviation industry give rise to the need for an optimal approach to choosing the parameters of agents and control processes.

The results of control are informational in nature and are not the final assessment of the effectiveness and efficiency of the management process. The performance in the control system is determined by feedback, and especially by the statistical properties of the feedback link. The risks at the output of the control agent are transformed by the feedback link and are “summed up” with the complement of the feedback [6]. The study of the statistical influence of the feedback link on the quality of control seems to be extremely important, and methodologically necessary, since without feedback, the meaning and possibility of control is lost.

An important problem in system and operational management and the task that is given attention in this paper is the assessment of the influence of mental factors on the decision-making process (PPR). In the scope of this topic, most of the works focused on the problem of qualitative analysis of the decision-making process, taking into account mental factors, and extremely rare works on modeling and quantifying the degree of their influence on the results of subjective management. The beginning of the psychological study of decision making as an interdisciplinary problem was laid by Ward Edwards in 1954, who can be called the founder of the study of the behavior of a real subject at the time of decision making [3]. One of the founders of the nature of the human psyche is the Swiss psychologist Carl Gustav Jung (1875-1961). In his fundamental work “Psychological Types”, Jung singled out extraverted and introverted psychotypes and four “mental functions”: thinking, feelings, sensations and intuition. The theory of psychological types was further developed in the works of A. Augustinavichute, Katharina Briggs, and Isabelle Briggs-Myers, as well as in domestic and foreign studies [19].

Such qualities of a decision maker (DM) as romanticism and practicality, optimism and pessimism are of great importance. One and the same person in different circumstances can be either a reinsurer or an adventurer, can both succeed and fail. The optimism of decision makers is often based on an overestimation of both their own capabilities and the prevailing circumstances. In any decision-making situation, there is always an acceptable “corridor” of possible outcomes, i.e. The decision maker is given the right to choose the best option on the principle of maximum utility and be responsible for this decision. The pessimism of the decision maker is based on an underestimated "bar" of their capabilities, and the prospects for the situation, while considering that an underestimated and stable option will be implemented without fail. Pessimism often manifests itself as excessive caution. This approach is typical for conservative processes. It is practically impossible to evaluate the entire set of variant compositions as shown in Table 1, including taking into account psychological factors, in one narrow problem under study, since the entire set of statistical risks in this environment represents a certain virtual space. In accordance with modern digital concepts, this virtual environment is a "virtual reality" and part of the "metaverse" [20]. "Metaverse", as noted in the publications, "is not a new term." The first concepts of the metaverse had only fantastic outlines associated with travel outside the galaxy. It is a cross between the real and fictional world. At present, the concept of "metaverse" has begun to acquire practical contours and penetrate many areas of life, such as: social networks, the real estate sector, investments, work, augmented reality, the cryptocurrency world, and online games. The new digital paradigm is to "look at life beyond the boundaries of ordinary understanding". Ultimately, a new digital approach called “digital transformation” is generated and proposed in [21]-[23]. Digital transformation, both at the functional and technological levels, has not yet acquired clear contours and differences from the traditional definition - digitalization. Attention is drawn to this fact and studied in detail in [24], [25]. The work [24] provides an extensive and in-depth analysis of the current state of digital transformation, which was made based on a study of 206 peer-reviewed articles. In the author's analysis of this subject matter state, the scientific and practical areas of digital transformation were considered and directions for future research are suggested. The analysis shows that the new digital reality has its own specifics in each business project and "managers must adapt their business strategy to new" digital technologies.

The work [25] proposes the results of a study to give a clear definition of the term "digitalization" and to distinguish between similar terms. The paper notes that the main goal of the transition to new digital technologies, especially the approach that integrates all known technologies, called "digital transformation", is the hope of increasing its competitive advantage, relying on service virtualization. Studying the new regulations and standards that have recently appeared in connection with the upcoming digital transformation, the following should be noted: at present, risk is an integral part of a person's "digital" life and is present in virtual and real forms of being, largely determining the "quality of life". at all stages of the life cycle.

2.1. Scientific problem

In the proposed study, attention is focused on assessing the quality of management in organizational and technical systems using the example of dynamic processes. The main scientific and practical idea of the study is to study the quality factors of managing complex multi-parameter systems under conditions of statistical uncertainty and fuzzy data, which lead to risks at the decision-making stage. The total management risk contains subjective and instrumental components. In connection with the introduction of artificial intelligence technologies in the digital transformation environment, the subjective component of risk is decreasing, but at the same time, the instrumental component of risk is increasing. The subjective risk factor is largely determined by the psychotype of the decision maker in the final phase of control. The instrumental component of risk is determined by the accuracy of control. Quantitative differentiated forecasting of these system components of risk by using formal methods is the research task. Integrated management risk assessment involves the study of a closed system at the stages of control, decision-making and correction of the result by a feedback link, taking into account its statistical properties, which is also the task of the study. Thus, the proposed study solves two scientific and practical problems: the development of a formal method for quantitative assessment of the quality of management of a complex multi-criteria organizational and technical system under the conditions of statistical uncertainty of management agents, taking into account feedback in the management of an object; formalization of the process of quantitative assessment of decision-making risks in the environment of statistical uncertainty of control agents and psychological factors of the decision maker.

3. METHOD

3.1. Research methods and materials

The work consists of theoretical studies based on a formal platform and experimental studies on the example of observing real mass dynamic processes. As the studied "human factor", the behavior and decision-making of a person in complex dynamic conditions of a traffic flow was evaluated, followed by psychological testing. For the processing of experimental data, the apparatus of mathematical statistics and the professional software package statistica were used. At the final phase of the research, an assessment is made of the adequacy of theoretical premises to practical data from the field of operation of real objects. The first step in the control process is the measurement operation. There are systematic and random errors in the measurement procedure. Systematic can be studied and eliminated or compensated. Random error is present in each case and is studied to identify statistical characteristics. The most important characteristic of a random error is the law of distribution. In most control and measurement problems, it is considered that the theoretical distribution of the measurement result is approximated by the normal law. In several recent works, it is proved that no more than 60% of measurements follow this law, and about 40% of measurements can be approximated by the Weibull laws and the equiprobable law. In literary sources and Internet resources, the concept of error is declared by the concept of "uncertainty".

3.2. Modeling the quality of feedback in the system control and decision making

The management process, as follows from Figure 1, consists of a sequence of steps. The first stage of control is the measurement of some controlled parameter in the information flow, which has a random nature and is indicated in the figure as Si. If the control is carried out by a set of parameters, then at the input of the control system there will be a set {Si}. The second operation is the comparison of the measured result with the standard values, which, as follows from Table 1, can limit the controlled parameter from below and be designated Sl, or limit from above and be designated St. If the standard has a two-sided restriction, then this is called a tolerance, which is determined from the expression Δ=St–Sl. If the controlled parameter is objectively or falsely registered outside the limits, then it becomes necessary to adjust the process. Correction is an operation to restore the functional performance of the control object. Regardless of the type of control process, the results of monitoring and restoring the normative functionality are of a stochastic nature, due to the uncertainty of the parameters and control conditions. Uncertainty generates errors and control risks [8]-[10]. In these studies, we limited ourselves to the consideration of the control system without taking into account feedback. But as follows from the classical works on processes and control systems, it is the feedback that ensures the stability of the system and the quality of the system as a whole. Therefore, considering all external and internal factors, it is legitimate to put forward a hypothesis about the random nature of the process of restoring the quality of the functioning of the system, and the statistical distribution density function of the correction result is designated as Z(S) Figure 1. In this formulation of the problem, it is advisable to use a simulation approach to develop a closed-loop control model. Graphical interpretation of the simulation process is shown in Figure 2.

Functionally and technologically, in real cases, the control unit and the "restoration of normative functions" unit appear to be autonomous systems. Figure 2 shows three distribution densities: f(S) is the distribution density function of the controlled parameter; $\varphi(S_{meas})$ – distribution density function of the measurement result; Y(Sp) is the distribution density function of the result of restoring the normative state of the object. To implement the computer experiment, a software application was developed, and testing of the simulation algorithm was implemented. Figures 3 and 4 show the results of the experiment.

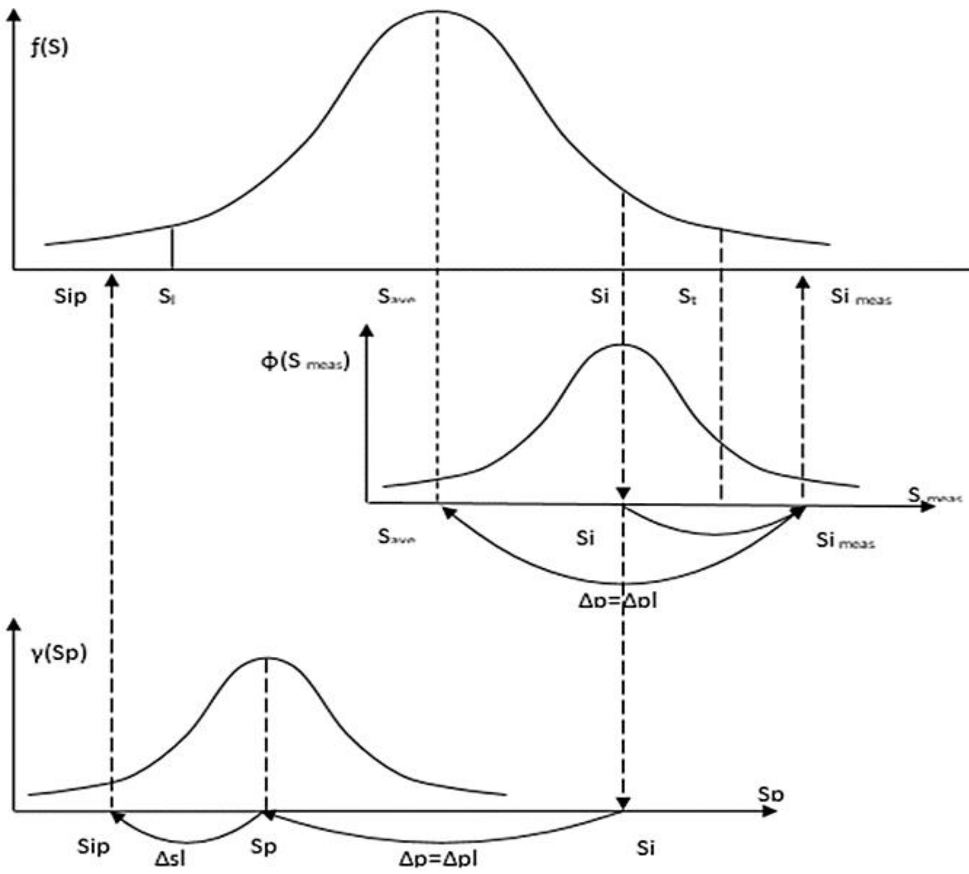

Figure 2. Graphical interpretation of the simulation process control and restoration of the normative parameters of the object

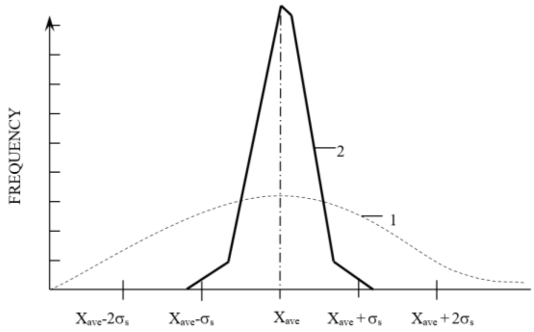

Figure 3. Result of correction at σ_k=0.25 σ_s

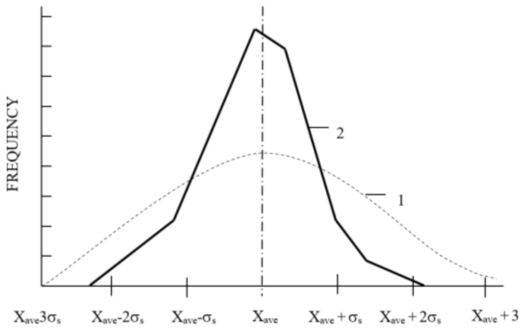

Figure 4. Result of correction at σ_k=0.5 σ_s

The figures show the results of control and correction at two values of feedback uncertainties after one cycle of correction of the controlled parameter. The correction results are presented as a distribution polygon of the correction result. The real objects of control refer to multi-parameter stochastic systems, which gives rise to the phenomenon of an integral property in the quality control of the entire system. To assess the functional or consumer quality of the system, they control a certain reasonable set of indicators, both differentiated by each indicator, and by the integral criterion of the quality of the object as a whole. The question of choosing and substantiating differentiated indicators (parameters) of control and the development of an integral quality criterion are, as a rule, the subject of a separate study in each specific case.

4. RESULTS OF THE RESEARCH

Modeling the quality of management, taking into account the psychotype of the decision maker. Practice and many theoretical studies prove that in decision-making, especially in critical situations, the subjective factor plays a decisive role, which is correlated with the psychotype of the person making the decision. This problem in the science of management is given considerable attention in the studies of many authors, but the main attention in the studies is focused on qualitative analysis. It is not possible to evaluate or predict quantitatively the influence of the psychological component on the result of decision-making, since it is extremely difficult to describe mathematically the actions of a person in a given situation.

To solve the problem of quantitative assessment of management results, taking into account psychological factors, the following hypotheses were adopted in the work:

- The results of decision-making are of a statistical nature;
- Mathematically, the result of the solution is approximated by a statistical distribution;
- Psychotype of the person making the decision is mathematically described by the statistical law of distribution.

To implement experimental statistical studies in this task, the problem arises of choosing a specific professional activity, where the psychotype of a person is quite clearly manifested, which is objectively recorded in regulatory documents and is easily provided by a representative volume of statistical sampling. These requirements are fully met by such an activity as driving a car, both at a professional and amateur level. To identify the driver's psychotype, special tests are used. The Eysenck questionnaire [26] was used as the baseline test in this study. In case of difficulties with adequate interpretation of the results, additional testing was carried out using a self-test questionnaire. The Eysenck questionnaire, designed to diagnose the individual psychological properties of a person, contains 57 questions. In practice, speed control was carried out by employees of the state inspectorate.

To establish the type of distribution laws at the first stage of the statistical study, an empirical distribution function of the entire set of observations was constructed in the form of a histogram of test scores according to the Eysenck questionnaire, which is shown in Figure 5. A visual analysis of the histogram shows that it has a three-module form, which allows us to put forward a hypothesis that the total set of measured data is a composition of three qualitatively heterogeneous samples with the corresponding distribution laws. At the first stage, three hypothetical samples were selected from the total population, for each of them empirical distribution functions were constructed in the form of histograms, and the main statistical characteristics were calculated. The empirical distribution function for the first sample - the supposed "pure introvert" (inhibited, cautious type) will have the following form Figure 6. For the second selected sample - "neuroticism" (rational type), the empirical distribution function will have the form represented by the histogram in Figure 7. For the third sample - "pure extrovert" (risk-oriented, optimist), the distribution function will have the following form Figure 8.

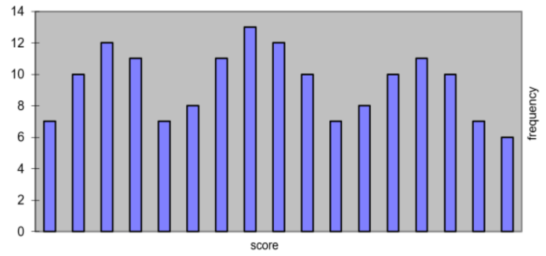

Figure 5. Histogram of the distribution of test scores according to the Eysenck questionnaire

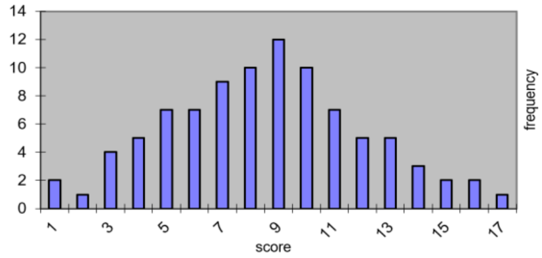

Figure 6. Histogram of the empirical distribution for "pure introversion""neuroticism"

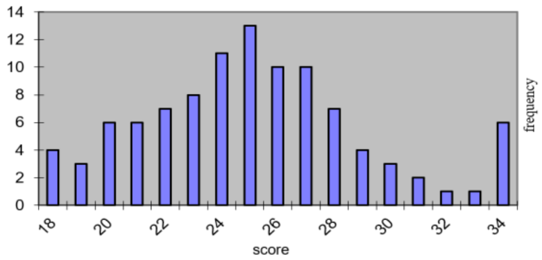

Figure 7. Empirical distribution for the selected group - "neuroticism"

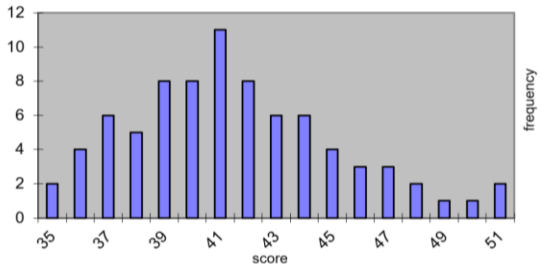

Figure 8. Empirical distribution for the selected group "extrovert"

To statistically test the hypothesis of qualitative heterogeneity of the three samples presented above, two methods were used: a method based on the use of the Fisher criterion and a method of qualitative difference in arithmetic means using t-statistics. The student statistic t, is calculated, on the basis of which a decision is made according to the formula:

$$t = \frac{Xave - Yave}{\sqrt{(m-1)Dx + (n-1)Dy}} \sqrt{\frac{mn(m+n-2)}{m+n}}$$

as a result, it was found that the hypothesis about the homogeneity of the samples and according to this method is rejected with a confidence level of 0.95. Further research was focused on the group of pure extraversion, as this group is the most psychologically risk-averse.

At this stage, the first task was to study the relationship between the speed regime of drivers and test scores. For this purpose, a group of drivers (extraverts) was identified from the entire flow of traffic participants on a controlled section of the road, and the speed of movement of each driver from this group was recorded. The next step was to calculate the main statistics and identify the distribution law, for which a distribution histogram was built, shown in Figure 9.

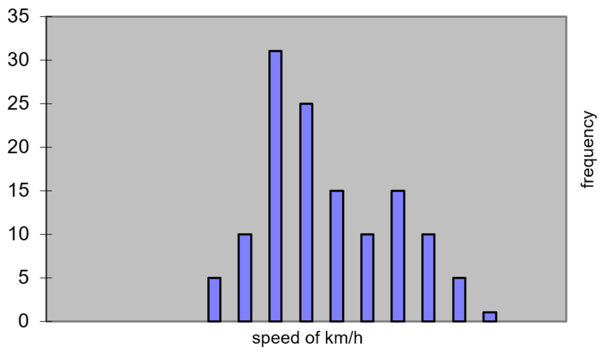

Figure 9. Histogram of the speed regime for the group "pure extrovert" (optimist)

As a result of a visual study of the shape of the histogram, two hypotheses about the distribution law were put forward: the hypothesis of the normal distribution law and the hypothesis of distribution according to the Weibull law. Evaluation of hypotheses according to the standard method using the Pearson criterion showed that the Weibull law is the most acceptable.

The analytical form of the distribution density of the Weibull law has the following form [11]:

$$Y(V) = \frac{\beta}{\alpha}(V-\gamma)e^{-\frac{(V-\gamma)^{\beta}}{\alpha}}$$

where α - scale parameter; β - form parameter; γ - position parameter.

$$\sigma_S = \sqrt{\alpha^{-\frac{1}{\beta}}\left[\Gamma\left(1+\frac{2}{\beta}\right)-\left(S_{aver}\cdot\alpha^{-\frac{1}{\beta}}\right)^2\right]} \quad (1)$$

$$SV\text{cp} = \alpha^{\frac{1}{\beta}}\Gamma\left[1+\frac{1}{\beta}\right]; \quad (2)$$

Form parameter β=1.75; α=1; γ = 90.
Using the experimental data, as well as (1) and (2), the parameters β, α, γ, were found, the values of which are: β=2.65, α=1, γ=80.

The next task was to quantify the risk of speeding violations by extrovert drivers. By analyzing empirical data, it was found that the probability of a risk of violation of the speed limit, for the maximum permissible speed on the highway of 110 km/h, is 0.47 (P=0.47). The results of measuring the vehicle speed in this case contain an instrumental error inherent in control devices.

To solve this problem, it is necessary to develop some model that would allow, given statistical parameters and distribution laws, to quantify and predict the level of risks in the control system. There is a probabilistic solution to this problem. However, in this case, the use of simulation modeling seems to be a more effective solution.

The error distribution, as a rule, is approximated by a normal law, the probability density function of which, in analytical form, has the following form:

$$f_1(\sigma_\varphi, V_i) = \frac{1}{\sqrt{2\pi}\sigma_\varphi}e^{-\frac{V^2}{2\sigma_\varphi^2}}, \quad (3)$$

where Vi - is the current speed value; σ_φ - is the standard deviation of the measurement error.

The simulation model algorithm works as follows. The values V_{av}, V_p, σ_φ, σ_v, N are entered, where N is the number of simulations. Random value generators are connected according to the laws of Weibull and Gauss. One cycle of simulations includes: generating V_i, then analyzing IF>V_p, where V_p is the limit, generating the measurement procedure V_{imeas}, comparing the measurement result V_{imem} with the standard V_p, if the measurement result V_{imeas} turned out to be less than V_p, then this is an error and the value of the error counter increases by unit. This is repeated N times, after which the number in the counter N_{um} is divided by N, which will be the probability of a false marriage (solution) - R_{fm}. Then, the previously found risk probability P is corrected (decreased) by the value of P_{fm}. Graphical interpretation of the results of a computer simulation experiment is shown in Figure 10.

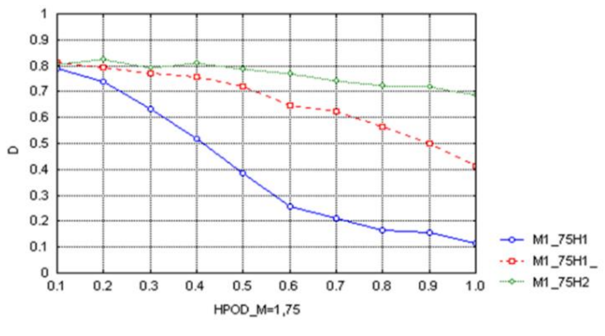

Figure 10. Reliability of decisions made in the vehicle control system

The middle curve corresponds to risky driving. Hypothetically, it was assumed that more accidents occur with risky object management (driving a car) than with other driving principles. However, the results of modeling driving outcomes, taking into account the model of the psychotype of a car driver and experimental data, do not confirm this hypothesis. This can be explained by the fact that risk subjects (cholerics) show high reactivity in dangerous situations. The greatest danger, both for the subject of control and for the environment, is very careful driving (pessimists).

These results may have practical applications in other industries, for example, in aviation and UAV control, where the "human factor" plays both a positive and a negative role. Special tests are already being used to identify psychological professional suitability, but they can be used as an information tool for a preliminary assessment of the quality of personnel. More advanced and promising technologies for these purposes open up digital transformation technologies, and especially the digital twin.

5. CONCLUSION

The purpose of the study is to formalize the methodology for quantitative risk assessment of control and decision-making under the conditions of statistical uncertainty of control agents and digital transformation of business processes. For a comparative analysis of systemic risks, simulation models of quantitative risk assessment for an open-loop system and a closed-loop system with feedback have been developed. The study has developed intellectual support for digital transformation processes in the format of a structural-functional and simulation description of control processes, decision-making and corrective action on the control object. In this context, two scientific and practical tasks were solved in the study: a simulation model of quantitative risk assessment of management of a complex multi-criteria organizational and technical system in the conditions of statistical uncertainty of management agents, taking into account feedback in the management of the object, was developed; a simulation algorithm for quantitative risk assessment of decision-making in the environment of statistical uncertainty of management agents and psychological factors of the decision-maker was developed. The psychological type of the person making the decision as a feedback link is described by the functions of statistical distribution according to the laws revealed empirically. Digital transformation technology is implemented using big data statistical reporting to build adequate management risk assessment models. Scientific and practical results of research are applicable in the control system of manned and unmanned vehicles. The proposed methodology should be considered as one of the approaches in the general task of quantitative assessment and predicting risks in the decision-making process, taking into account the psychological type of a person in complex dynamic conditions.

ACKNOWLEDGEMENTS

The article was carried out within the framework of the project of the Ministry of Education and Science of the Republic of Kazakhstan for grant financing of fundamental and applied scientific research of young postdoctoral scientists under the Zhas Galym project for 2022-2024. IRN: AP14972524 - "Development of VLC technologies in the management of unmanned vehicles."

REFERENCES

[1] C. Machado and J. P. Davim, *Organizational management*, Palgrave Macmillan UK, 2016.
[2] S. N. Luko, “Risk assessment techniques,” *Quality Engineering*, vol. 26, no. 3, pp. 379-382, 2014, doi: 10.1080/08982112.2014.875769
[3] O. I. Larichev, *Theory and methods of decision-making, as well as the Chronicle of events in Magic Countries*: Textbook. — M.: Logos, 2000.
[4] K. Alibekkyzy, W. Wojcik, K. Vyacheslav, and S. Belginova “Robust data transfer paradigm based on VLC technologies,” *Journal of Theoretical and Applied Information Technology*, vol. 99, no. 3, Feb. 2021.
[5] N. Wiener “Cybernetics, or control and communication in animal and machine,” *[translation from English], M.: Nauka; Main edition of publications for foreign countries*, p. 344, 1983.
[6] L. Sumaryanti, D. H. Kusuma, R. Widijastuti, and M. N. Muzaki, “Improvement security in e-business systems using hybrid algorithm,” *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 19, no. 5, pp. 1535-1543, 2021, doi: 10.12928/telkomnika.v19i5.20403.
[7] K. Alibekkyzy, K. Koshekov, W. Wojcik, and V. Kornev, “VLC data transmission systems: Monograph (in Russian),” - Ust-Kamenogorsk, "VKPK ARGO", p. 141, 2021.
[8] R. K. Radjabov, “Modeling of microeconomics (in Russian),” Dushanbe: "Irfon", 2017, pp. 16-31.
[9] K. K. Chandriah and N. V. Raghavendra, “Multi-objective optimization for preemptive & predictive supply chain operation,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 10, no. 2, pp. 1533-1543, 2020, doi: 10.11591/ijece.v10i2.pp1533-1543.
[10] Y. Marzhan, K. Talshyn, K. Kairat, B. Saule, A. Karlygash, and O. Yerbol, “Smart technologies of the risk-management and decision-making systems in a fuzzy data environment,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 28, no. 3, pp. 1463-1474, Dec. 2022, doi: 10.11591/ijeecs.v28.i3.pp1463-1474.

[11] V. A. Kornev, A. A. Makenov, A. H. Mashekenova, and R. C. Radjabov, "Quality assessment of multi-parameter control of vehicle complex systems efficiency," *News of National Academy of sciences of Republic of Kazakhstan: Series of geology and technical sciences*, vol. 2, no. 440, pp. 96-102, 2020, doi: 10.32014/2020.2518-170X.36.

[12] V. A. Kornev, G. Sagidullina, and T. Kaisaruly "Models for predicting the reliability of instrumental diagnostics (in Russian)," *Ust-Kamenogorsk, VKPK ARGO LLP*, p. 160, 2020.

[13] J. Ferber, O. Gutknecht, and F. Michel, "From agents to organizations: an organizational view of multi-agent systems," *AOSE 2003: Agent-Oriented Software Engineering IV*, Springer Berlin Heidelberg, 2004 pp. 214-230, doi: 10.1007/978-3-540-24620-6_15

[14] O. Gutknecht and J. Ferber, "The MADKIT agent platform architecture," *AGENTS 2000: Infrastructure for Agents, Multi-Agent Systems, and Scalable Multi-Agent Systems*, vol 1887. Springer, Berlin, Heidelberg, 2001, pp. 48–55, doi: 10.1007/3-540-47772-1_5

[15] V. A. Kornev, A. A. Makenov, A. H. Mashekenova, and R. C. Radjabov, "Quality assessment of multi-parameter control of vehicle complex systems efficiency," *N E W S of the Academy of Sciences of the Republic of Kazakhstan*, vol. 2, no. 440, pp. 96– 102, 2020, doi: 10.32014/2020.2518-170X.36.

[16] M. Yesmagambetova, T. Ten, T. Ospanova, S. Belginova, and K. Alibekkyzy "Digital modeling of decision-making risks in natural and man-caused critical situations," *Journal of Theoretical and Applied Information Technology*, vol.100, no 15, pp. 4628-4640, 2022.

[17] K. Mahmood and N. A. Ismail, "Application of multibody simulation tool for dynamical analysis of tethered aerostat," *Journal of King Saud University – Engineering Sciences*, vol. 34, pp. 209–216, 2022, doi: 10.1016/j.jksues.2020.09.005.

[18] S. Gomaa, R. Emara, O. Mahmoud, and A. N. El-hoshoudy, "New correlations to calculate vertical sweep efficiency in oil reservoirs using nonlinear multiple regression and artificial neural network," *Journal of King Saud University Engineering Sciences*, vol. 34, pp. 368–375, 2022, doi: 10.1016/j.jksues.2021.07.010.

[19] M. Alenezi, "Ontology-based context-sensitive software security knowledge management modeling," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 10, no. 6, pp. 6507–6520, 2020, doi: 10.11591/ijece. v10i6.pp6507-6520.

[20] C. H. Juang, L. Wang, Z. Liu, and N. Ravichandran, "Robust geotechnical design of drilled shafts in sand: new design perspective," *Journal of Geotechnical and Geoenvironmental Engineering*, vol. 139, no. 12, pp. 2007-2019, 2013, doi: 10.1061/(ASCE)GT.1943-5606.0000956

[21] D. Dang-Pham, A.-P. Hoang, D.-T. Vo, and K. Kautz, "Digital Kaizen: an approach to digital transformation," *Australasian Journal of Information Systems*, vol. 26, 2022, doi: 10.3127/ajis.v26i0.3851

[22] "On approval of the State Program "Digital Kazakhstan" (in Russian), Decree of the Government of the Republic of Kazakhstan, Dec. 12, 2017, № 827. Accessed: May 30, 2018. [Online]. Available: https://adilet.zan.kz/rus/docs/P1700000827.

[23] "Digital economy of the Russi an Federation (in Russian)," Static.government, 2017. Accessed: May 30, 2018. [Online]. Available: http://static.government.ru/media/files/9gFM4FHj4PsB79I5v7yLVuPgu4bvR7M0.pdf.

[24] J. Reis, M. Amorim, N. Melão, and P. Matos, "Digital transformation: a literature review and guidelines for future research," *WorldCIST'18 2018: Trends and Advances in Information Systems and Technologies*, Mar. 2018, pp. 411-421, doi: 10.1007/978-3-319-77703-0_41.

[25] J. Reis, M. Amorim, N. Melão, Y. Cohen, and M. Rodrigues, "Digitalization: a literature review and research agenda," *Proceedings on 25th International Joint Conference on Industrial Engineering and Operations Management – IJCIEOM*, Mar. 2020, pp 443-456, doi: 10.1007/978-3-030-43616-2_47.

[26] M. Alenezi, "Ontology-based context-sensitive software security knowledge management modeling," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 10, no. 6, pp. 6507–6520, 2020, doi: 10.11591/ijece. v10i6.pp6507-6520.

BIOGRAPHIES OF AUTHORS

Koshekov Kairat he is is Doctor of Technical Sciences, Professor, Vice-Rector for Science and International Cooperation Civil Aviation Academy, Almaty, Kazakhstan. He defended his doctoral degree in the specialty "Automation and control of technological processes and industries." He is the author or co-author of more than 100 publications and patents on the automation of technical processes. His research interests include LED system, data transmission, unmanned vehicles. Currently he is the head of several scientific and technical projects. He can contact him by e-mail: kkoshekov@mail.ru.

Alibekkyzy Karlygash received an academic degree of Master of Engineering Sciences in the specialty "Instrumentation" and a Ph.D. in the specialty "Automation and Control" from the East Kazakhstan State Technical University. D. Serikbayeva (EKSTU), Ust-Kamenogorsk, Kazakhstan, in 2014 and 2022, respectively. She is currently a Senior Lecturer, PhD Doctor of the School of Information Technologies and Intelligent Systems of the East Kazakhstan Technical University. D. Serikbaeva, Ust-Kamenogorsk, Kazakhstan. She is the author or co-author of more than 15 publications. Her research interests include LED systems, data communication, self-driving vehicles. She can contact her by e-mail: karlygash.eleusizova@gmail.com.

Toiganbayev Beglan is a doctoral student in the specialty 8D07101 "Aviation equipment and technology", received an academic degree of Master of Technical Sciences in the specialty "Aviation Engineering and Technology" at the Academy of Civil Aviation, Almaty, Kazakhstan, 2014. Currently, he is a teacher at the Academy of Civil Aviation. He is the author or co-author of more than 5 publications. Research interests: unmanned aerial vehicle, control systems, differential equations. He can be contacted by email: toiganbayev.b@gmail.com.

Belginova Saule received the Master of Engineering academic degree of specialty "Mathematical and computer modeling" and the Ph.D. degree of specialty Information Systems from D. Serikbayev East Kazakhstan State Technical University (EKSTU), Oskemen, Kazakhstan, in 2014 and 2020, respectively. At the present she is an associate professor of Information Technology department in University "Turan", Almaty, Kazakhstan. She has authored or coauthored more than 40 publications. Her research interests include soft computing, mathematical and computer modeling of processos, intellectual analysis of medical data. She can be contacted at email: sbelginova@gmail.com.

Keribayeva Talshyn is a doctoral student in the specialty 8D07101 "Aviation equipment and technology", received an academic degree of Master of Technical Sciences in the specialty "Aviation Engineering and Technology" at the Civil Aviation Academy, Almaty, Kazakhstan, 2014. Currently, she is a lecturer at the Civil Aviation Academy. She is the author or co-author of more than 7 publications. Her research interests are unmanned aerial vehicle, control system, differential equation. She can be contacted at email: talshyn.keribayeva@agakaz.kz.

Tulaev Viktor professor, associate professor of the department "Theory and methods of physical and military education" Non-profit limited company "Manash Kozybayev North Kazakhstan university", Petropavlovsk, Kazakhstan. He is the author or co-author of more than 100 publications and patents on process automation. His research interests include LED system, data transmission, unmanned vehicles. He can contact him by email: tvk30091949@mail.ru.

Koshekov Abai received an academic degree of Master of Technical Sciences in the specialty 6D071900 - "Radio engineering, electronics and telecommunications" and a PhD in the specialty 6D071900 - "Radio engineering, electronics and telecommunications" Non-profit limited company "Manash Kozybayev North Kazakhstan university", Petropavlovsk, Kazakhstan. Currently he is a senior lecturer, doctor PhD at the Civil Aviation Academy Almaty, Kazakhstan. He is the author or co-author of more than 15 publications. He can contact him by e-mail: abai_koshekov@mail.ru.