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Analysis of a balanced safety performance indicator as a key element of operational controlling in the ATS organization

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Abstract: Controlling is considered as a versatile modern focus of management. It is widespread in various fields of human activity but has not found direct application in civil aviation yet. Meanwhile, any aviation organization is subject to the general laws of management, therefore, controlling can and should find its application in the management of an aviation organization. Due to the particular importance of safety management considerations, controlling, as a management concept that allows you to control processes rather than results, fits seamlessly into the procedures of safety management systems (SMS) of aviation service providers. In particular, the development and monitoring of safety performance indicators (SPI) can be considered as a key element of operational controlling. In the SMS, the procedure to deal with the SPI, in conjunction with the risks mitigation procedure for safety, is an essential component of the entire system. To ensure the effectiveness of this procedure in the Air Traffic Service (ATS) organization, it is necessary to develop a balanced overall SPI. As the analysis showed, the indicators applicable in ATS organizations are focused on considering only incidents of the same "weight" and do not objectively reflect a level of safety assurance at ATS and its dynamics. The article presents a variant of developing a revised balanced indicator, which considers less significant deviations from the proper ATS system operation, errors and violations of personnel. The indicator was developed on the basis of the expert survey of ATS specialists. Monitoring and predicting of indicators are also important tasks of operational controlling. These problems can be solved by various methods, the applicability and comparative effectiveness of some of them are discussed in this article. All calculations are based on real data of one of the major ATS organizations of the Russian Federation.

Key words: operational controlling, air traffic service, aviation safety, expert assessments, predicting.

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Анализ сбалансированного показателя безопасности полетов как ключевой элемент оперативного контроллинга в организации по ОВД

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Аннотация: Контроллинг рассматривается как универсальное современное направление менеджмента. Он широко распространен в различных областях человеческой деятельности, но в гражданской авиации пока не нашел прямого применения. Между тем любое авиапредприятие подчиняется общим законам управления, следовательно, контроллинг может и должен найти свое место в управлении авиационной организацией. Ввиду особой важности для авиации вопросов управления безопасностью полетов контроллинг как концепция менеджмента, позволяющая контролировать процессы, а не результаты, органично вписывается в процедуры систем управления безопасностью полетов (СУБП) поставщиков авиационных услуг. В частности, разработка и мониторинг показателей эффективности обеспечения безопасности полетов (SPI) может рассматриваться как ключевой элемент оперативного контроллинга. В СУБП процедура работы с SPI, наряду с процедурой управления рисками для безопасности полетов, является важнейшим компонентом всей системы. Для обеспечения эффективности этой процедуры в организации по обслуживанию воздушного движения (ОВД) необходимо разработать сбалансированный общий SPI. Как показал анализ, применяемые в организациях по ОВД показатели ориентированы на учет только инцидентов, причем с одинаковым «весом», и не отражают объективно уровень обеспечения безопасности полетов при ОВД и его динамику. В статье представлен вариант разработки нового сбалансированного показателя, который учитывает и менее значимые отклонения от нормального функционирования системы ОВД, ошибки и нарушения персонала. Показатель разработан на основе экспертного опроса специалистов по ОВД. Мониторинг показателей и их прогнозирование также являются важными задачами оперативного контроллинга. Эти задачи могут решаться различными методами, применимость и сравнительная эффективность некоторых из них обсуждаются в данной статье. Все расчеты выполнены на основе реальных данных одной из крупных организаций по ОВД Российской Федерации.

Ключевые слова: оперативный контроллинг, обслуживание воздушного движения, безопасность полетов, экспертные оценки, прогнозирование.

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Introduction

Controlling represents a modern advanced theoretical and practical focus of management which stipulates setting up an integrated system to facilitate the organization management aimed at coordinating the interaction of management systems and control of their effectiveness. A brief definition by the economists of repute E.A. Gomonko, T.F. Tarasova is given in [1]: "**controlling** is a unified management system of the process to achieve objectives and entity performance".

If at the onset, controlling was interpreted as a system of entity profit management [2], then in the modern sense, the term comprises risk-management, quality management, the information support system, management of a set of main indicators and a system of implementation of the decisions made. A concept of controlling has been used in the western science and management practice since the 19th century. However, in Russia, it has not gone mainstream since it is associated with the term "control". A word "controlling" derives from the English verb *to control*, but this verb has other meanings such as to manage, monitor, track, configure, regulate. The difference of controlling from control by [3] is as follows: **Control** is monitoring performance upon expiration of the term. **Controlling** is a management concept that allows us to supervise processes rather than performance, helps to define a phase of the process where a disruption event took place, obtain feedback, and make adjustments in due time.

According to Professor A.I. Orlov [4], currently, controlling principles are, in fact, applied quite on a large scale. The issues of controlling were considered, at least, in 40% of the reports at the International Conferences of the Russian Academy of Sciences of the Institute of Control Sciences "Management of the Evolution of Large-Scale Systems", which have been held since 2013. The authors [5] assert that successfully developing global major companies have pursued the concept of controlling for a long time, even though do not use this term.

The literature on the different aspects of controlling is extensive. The Scientific and Educational Center "Controlling and Managerial Innovations" works in the Bauman Moscow State Technical University under the charge of Professor S.G. Fal'ko and Professor A.I. Orlov http://cmi.bmstu.ru.

According to [4], **strategic controlling** is developing objectives and focal points in the light of the medium and long term, proposing ways to attain objectives and solve problems (principle "do the proper thing"). **Operational**

controlling deals with timely arrangements within a limited span of time to eliminate deviations of actual indicators from planned ones and fulfils a short-term prediction (principle "do the thing in a right way").

Management of an aviation entity obeys the objective management laws, which means the controlling concept is implemented in its activity.

1. Application of controlling methods in aviation organization safety management

In various branches of production, controlling examples of different safety aspects can be encountered.

A concept "risk-controlling", integrating risk management into all fields and processes of management, is formulated in the entity policy of risk management [6].

The controlling methods are employed in the industrial safety management. The article [7] proposes the system of operational controlling indicators of safety in the oil and gas company. It encompasses an analysis of incidents, costs on preventive measures to avoid accidents and incidents, penalty sums, occupational health service. The point assessment of an indicator and their summation to form an overall coefficient is stipulated.

The article [8] proposes to include issues to ensure economic, transport, technological, and informational safety for the defense industry enterprise into controlling.

Safety management is an integral part of a general process of the aviation organization management and implemented by the Safety Management System (SMS). Let us specify the article [9] as an example of embedding safety issues into the system of controlling. The author, speaking about "the key elements of the airline risk-controlling", includes them as components into the system of safety performance. However, without being familiar with the SMS principles, he includes such elements as "drawing up a list of abusive passengers" as well as "expansion of a number of partners as part of code-sharing" into the system.

Issues of ensuring security (protection from unlawful interference) are also important for an operator. Moreover, as stated above, controlling incorporates the quality control system as well. Hence, within the framework of the controlling concept, setting up of the integrated system of safety management, which encompasses the SMS, the quality management system, as well as the systems of security and occupational safety management, can be implemented. It complies with the best practices in Civil Aviation and will allow for the allocation of the aviation organization resources to be optimized.

For an aviation organization, the structure of controlling as an integrated system of management, considering a general scheme from [10, 11], can be represented in the form in Figure 1. The SMS elements that fit seamlessly into this structure are highlighted.

An assessment and monitoring of the Safety Performance Indicators (SPIs) is one of the two major SMS constituents. The development of a balanced SPI and its monitoring are substantial considerations of operational aviation organization controlling including ATS organization. The development of the prediction technique for safety performance is also of interest for operational controlling.

2. Forming a balanced Safety Performance Indicator in an Air Traffic Service organization

Confirmation that the safety of the aviation organization is maintained at an acceptable level is ensured by the implementation of component 3 of SMS called "Safety assurance".

Element 3.1 Safety performance monitoring and measurement is the core of this component.

The given analysis showed that relative indicators of flying hours per one aviation incident and the number of aviation incidents per 100000 flight hours are used to assess safety performance at the level of the State ATM Corporation and its branches. For this purpose, major aviation incidents, which are considerably more serious in terms of severity, are not emphasized from a total number of aviation incidents. Con-

Fig. 1. The general structure of controlling in an aviation organization
установление целей – establishing targets; планирование и управленческий учет – planning and managerial accounting; управление и обмен информацией – data management and sharing; риск-менеджмент – risk-management; контроллинг – controlling; выработка рекомендаций – issuing recommendations; анализ отклонений – analysis of deviations; управление качеством – management of quality; контроль – control; мониторинг показателей – indicator monitoring; стратегические риски-strategic risks; экономические риски – economic risks; финансовые риски – financial risks; риски производственной безопасности – risks for industrial safety; риски для безопасности полетов – risks for aviation safety; риски для авиационной безопасности – risks for air security; риски информационной безопасности – risks for data security; экологические риски – ecological risks; экономические показатели – economic indicators; показатели производственной безопасности – indicators of industrial safety; показатели авиационной безопасности – air security indicators; показатели безопасности полетов – aviation safety indicators; показатели информационной безопасности – data security indicators; показатели экологической безопасности – indicators of ecological safety

sidering all aviation incidents with the equal weight, while calculating the SPI, distorts an idea about the safety level. On the other hand, if aviation incidents are not available over the reporting period, the SPI will amount to zero in an entity which formally indicates an ideal status quo with safety performance. But, at the same time, the same organization can have quite a considerable number of discrepancies according to objective control data and/or findings during Rostransnadzor. The data is not considered at all in the currently applicable SPI of the SMS organization.

A similar problem in the SMS of other air entities is resolved by the introduction of additional SPIs. For example, the air entities (Aeroflot, S7, etc.) use “an integral indicator” developed by the Chair of Aviation Safety of the Moscow Civil Engineering Institute (currently the Moscow State Technical University of Civil Aviation) [12] in the 80s last century. While calculating an integral indicator, not only aviation events (aircraft occurrences, aviation incidents, and work-related incidents) can be interpreted as the term "event", but also precursors, i.e., facts affecting safety performance but not having a status of an aviation event. The indicator is based on an event attributed to one of the "problematic situations" which can be acceptable for an aviation organization but interpreted with difficulty for an ATS organization.

Another example of such an indicator is the indicator of "a based-risk event" (EBR), proposed by the International Group ARMS [13]. This method assesses each event similar to an aviation incident or a precursor. It is adopted based on expert answers to two questions:

1. How close were we to an aviation accident?
2. What damage would occur while developing an event?

Answers are processed using a special matrix to obtain a quantitative assessment of the indicator "classifier of event risk" (ERC) in conditional units from 0 to 2500. The method is employed in the air entities SAS, Finnair, etc.

A simplified variant of an assessment, focused on not significant events, is proposed by S.A. Tolstykh [14] to use aerodrome operators in the SMS. The calculation of "a coefficient of risk for deviations and events" (KPOS) is carried out under a formula

$$KPOC_i = \frac{0,25 n_C + n_B + 2 n_A}{N_i}, \quad (1)$$

where $KPOC_i$ – the SPI in the i-period (month, week);

n_A, n_B and n_C – the number of events by risk categories (A, B, C).

But in the formula (1), the ratio between weights is expressed as 1:4:8, such proportions can be applied only for insignificant and medium incidents by severity.

Thus, the indicators under consideration cannot be recommended as a balanced SPI for an ATS organization.

On the assumption of the conducted research of the existing structure of deviations from regulations, violations, and events under ATS, it is proposed to introduce a 4th level indicator $K_{БП\text{-}I}$ as the balanced SPI per 10000 served flights over k-th span of time:

$$K_{БП-k} = \frac{C_1 n_1 + C_2 n_2 + C_3 n_3 + C_4 n_4}{N_k} \times 10000, \quad (2)$$

where n_1, n_2, n_3, n_4 – the number of recorded events in an organization over k-th span of time by groups of severity (gr. 1 – minimum severity, gr. 4 – maximum one);

C_1, C_2, C_3, C_4 – the weight coefficients for deviations and events of the group (tab. 1).

Fitting of weight coefficients using the Delphi method

Fitting of weight coefficients in the formula (2) is carried out based on the expert survey. In order to solve a problem, an expert survey, developed in the late 1950s in the USA [14, 15], was executed using the Delphi method. A unique feature of the method is that experts make assessments irrespective of each other in the first phase, hereafter, each expert gets familiar with group assessment results, and another round of assessing is executed. The recommendations concerning the procedure by the Delphi method are stated in the Russian National Standard[1], and voluminous relevant literature is provided. There is no theoretical substantiation of the method, but it is largely used to formulate expert opinions while solving complex formalizable problems.

In conformity with the principles of the method, a group of 10 experts was set up in the preliminary phase, maintaining confidentiality. Questionnaires were drawn up, and the first round of the survey was conducted. In the second phase, the evaluation was carried out. In the first phase, the most considerable discrepancies occurred among experts 3, 4 and 6 for minimum significance, and among experts 3 and 5 for deviations Experts referred to insufficiently clear understanding of the problem. During another survey, experts 3, 4 and 6 proposed amendments, and these assessments were recognized ultimate (tab. 2).

[1] The State Standard R -58771-2019. (2020). Risk management. Risk assessment technologies. Moscow: Standartinform, 90 p. (in Russian)

Table 1

Criteria for assigning deviations and events to severity groups

№	Severity	Examples	C
1	Minimum	Insignificant deviations in the ATC work from the technology or from the radiotelephony phraseology, insubstantial errors while transmitting information to a flight crew under inspections or FDR/CVR data. Radio communication equipment, navigation aids failures, monitoring with the timely changeover switching for backup. Complaints of flight crews about the radio communication equipment operation which have not caused flight plan updating or the go-around procedure	C_1
2	Medium	Crude ATC errors in the technology of work or in the radiotelephony phraseology which have not caused an aviation event but recorded as a potential traffic conflict by FDR/CVR data corrected by a flight crew or the adjacent en-route control. Radio communication equipment, navigation aids failures and monitoring which complicated the ATC work or the flight crew work (according to flight crew reports) but not attributed to an aviation event	C_2
3	Hazardous	Aviation incidents. Separation violation and near-miss not attributed to serious incidents. Radio communication equipment, navigation aids failures and monitoring not attributed to serious incidents	C_5
4	Critical	Serious aviation incidents. Hazardous proximity of aircraft. Radio communication equipment, navigation aids failures and monitoring attributed to serious incidents	C_4

Table 2

The results of expert assessments of weight coefficients

Expert	**Expert assessments**				**∑**	**Assessment summarizing to the unified scale**				**∑**
	C_{i1}	C_{i2}	C_{i3}	C_{i4}		C_{i1-s}	C_{i2-s}	C_{i3-s}	C_{i4-s}	
1	1	4	7	12	24	0.04	0.17	0.29	0.50	1.00
2	1	5	10	15	31	0.03	0.16	0.32	0.48	1.00
3	1	4	6	12	23	0.04	0.17	0.26	0.52	1.00
4	1	3	6	10	20	0.05	0.15	0.30	0.50	1.00
5	1	3	4	6	14	0.07	0.21	0.29	0.43	1.00
6	2	6	10	15	33	0.06	0.18	0.30	0.45	1.00
7	1	5	8	10	24	0.04	0.21	0.33	0.42	1.00
8	1	3	6	10	20	0.05	0.15	0.30	0.50	1.00
9	1	4	8	10	23	0.04	0.17	0.35	0.43	1.00
10	1	3	7	10	21	0.05	0.14	0.33	0.48	1.00
	Average values $MO(C_{jM})$					0.048	0.172	0.308	0.472	
	Normalized averages CjN					1.000	3.573	6.384	9.781	
	Weight coefficients C_j					*1*	*4*	*6*	*10*	
	Mean-root-square deviations					0.011	0.024	0.026	0.036	
	Variation coefficients					0.228	0.139	0.085	0.076	

Expert coordination was assessed by a coefficient of variation as good. Transferring of the original expert point assessments C_{ij} to the assessments in the unified scale C_{ij-s} were conducted using the formula

$$C_{ij-s} = \frac{C_{ij}}{\sum_{j=1}^{4} C_{ij}}.$$

Normalized average values C_{jN} of each weight were calculated:

$$C_{jN} = \frac{C_{jM}}{C_{1-s}},$$

where C_{jM} – the average value of weight in the unified scale for the j-th coefficient,

$C_{1-s} = 0{,}048$ – the weight value for the coefficient C_1 in the unified scale.

Plugging findings into the formula (1), we will derive a final formula to calculate the SPI for an ATS organization.

$$K_{БП-k} = \frac{n_1 + 4n_2 + 6n_3 + 10n_4}{N_k} \times 10000. \quad (3)$$

According to the formula (3), calculations $K_{БП-k}$ must be made in an ATS organization every month individually for the ATS (air traffic controllers) as well as for the service of radiotechnical support (for engineers and technicians) and shown on a screen.

3. Methods of SPI monitoring during operative controlling in an ATS organization

An analysis of deviations in the management system is one of the most major objectives of operative controlling [5]. While monitoring the process of varying controlled values, deviations from planned values are revealed. In this case, it is necessary to decide if these deviations are within tolerance or their availability cannot be neglected, and the correction is required. It is fully referred to the SPI.

The following basic types of monitoring are used:

- direct monitoring of an indicator;
- methods of a simple and weighted moving average;
- method of Shewhart checklists and cumulative sums.

While direct monitoring and monitoring by means of a moving average, a targeted level (Safety Performance Target (SPT) and two threshold levels (triggers), calculated by data from previous years in accordance with the methodology recommended by the ICAO in the Safety Management Manual the 3d edition[2], considering the amendment, recommended by our article [16] are distributed on the screen.

The diagram of direct monitoring shows the excess of triggers but has a sawtooth view and is not sufficiently informative to identify tendencies. For the purpose of smoothing temporal series, **the methods of moving average** [17], which can be used for the SPI, are successfully employed. During a span of smoothing the 1 quarter (3 months) calculation of the indicator for the r-th month for a moving average $K_С^i$ is conducted according to the formula:

$$K_С^r = \frac{w_{r-2}K_{БП}^{r-2} + w_{r-1}K_{БП}^{r-1} + w_r K_{БП}^r}{3},$$

where $K_{БП}^{r-2}$, $K_{БП}^{r-1}$ end $K_{БП}^r$ – the indicators over 3 previous months;

w_{i-2}, w_{i-1}, w_i – the weight coefficients, in addition, $w_{r-2} + w_{r-1} + w_r = 3$.

For a simple average $w_{r-2} = w_{r-1} = w_r = 1$, and for a weighted one, they are selected so that recent events could be considered to a greater extent than remote by time.

Table 2 gives actual data of one of the ATS organizations of the Russian Federation over 2023, Figure 2 demonstrates the diagrams of direct monitoring $K_{БП}$ as well as a simple and weighted moving average ($w_{r-2} = 0.75$, $w_{r-1} = 1$, $w_r = 1.25$) by data.

The moving average methods make it possible to obtain a detailed picture of variation $K_{БП}$, particularly under its abrupt fluctuations. Each value represents a mean indicator over a period

[2] Doc. 9859: Safety Management Manual (SMM) (2013). 3 rd ed. ICAO, 318p.

Table 3

Data from one of the ATS organizations for 2023

Level of the events	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0	3	0	1	9	6	8	23	0	0	0	14
2	12	15	13	22	25	20	16	15	22	17	21	14
3	0	1	0	1	2	1	1	3	0	0	0	2
4	0	0	0	0	0	0	0	0	0	0	0	0
Served aircraft	43747	38947	44589	45522	51739	55954	59558	61342	61897	57930	55890	46122
Aviation safety co-efficient	10.97	17.72	11.66	20.87	23.39	16.44	13.10	16.47	14.22	11.74	15.03	17.78
S	−1.93	2.89	1.65	9.62	20.11	23.65	23.84	27.41	28.73	27.57	29.69	34.57

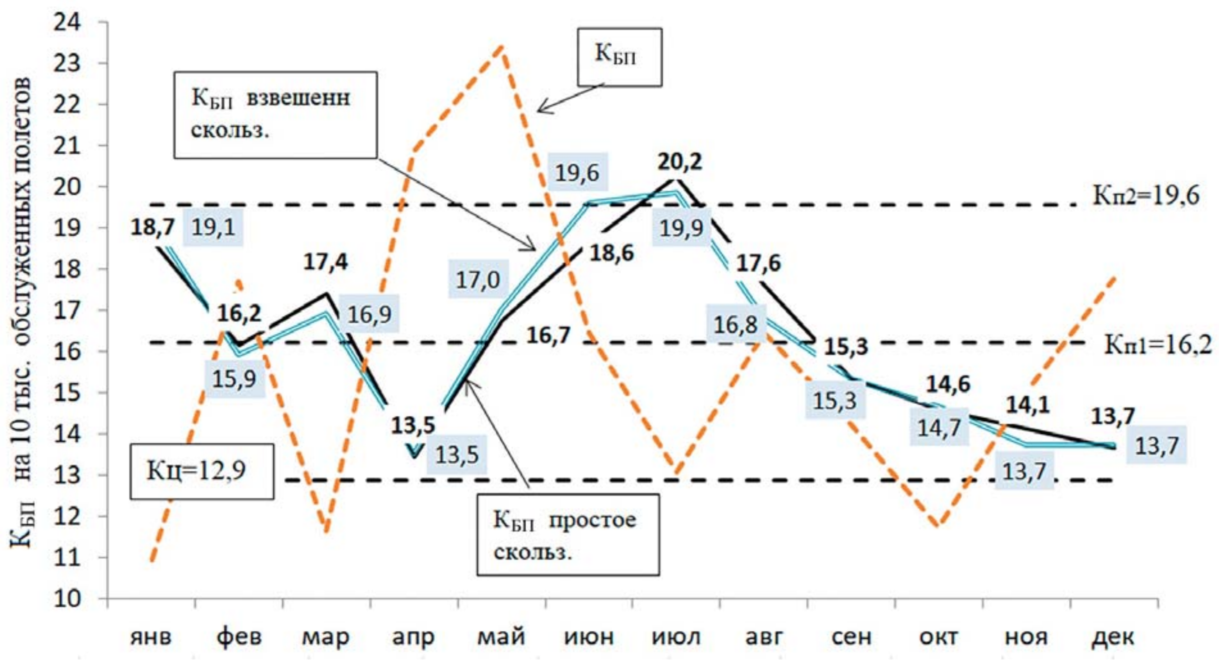

Fig. 2. Monitoring the SPI of the ATS organization in 2023 by various methods

of smoothing. The method of a simple and weighted moving average is employed in some airlines for monitoring various safety performance indicators [18].

The methods of Shewhart checklists and the checklists of cumulative sums [19] are massively used to reveal deviations of product parameters from their target values in controlling of industrial enterprises. In the airline management, there is also experience of applying checklists [4] while solving problems of one of the controlling types.

The most appropriate for problems of the SPI assessment is the **“cumsum method”, founded**

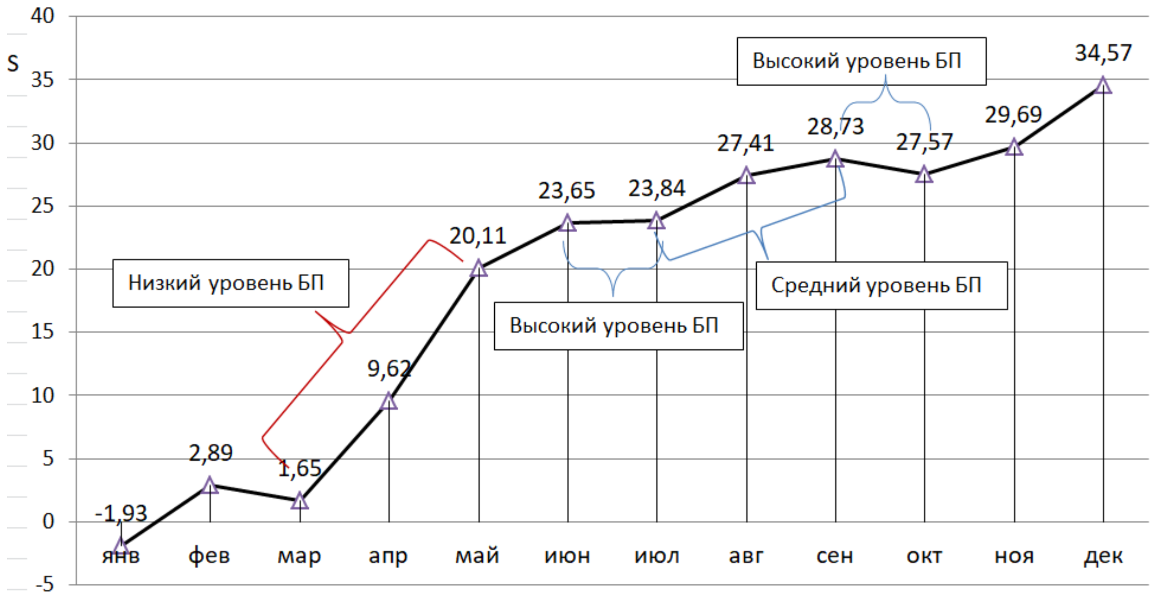

Fig. 3. A map of the cumulative amounts of the $K_{БП}$ indicator of one of the ATS organizations in 2023
высокий уровень БП – the high level of aviation safety; низкий уровень БП – the low level of aviation safety; средний уровень БП – the medium level of aviation safety

on considering cumulative sums, recommended by the State Standard R ISO 7870-4-2013[3].

The formula of calculating cumulative sums in conformity with [19] in agreed notations is represented as:

$$S_r = \sum_{i=1}^{r}\left(K_i \middle| -K_{ц}\right) = S_{r-1} + \left(K_r - K_{ц}\right). \quad (4)$$

The diagram in Figure 3 is built according to data from Table 2 based on the calculations under the formula (4). The graph shows variations of a level of safety performance respectively the standard-compliant level, which is relevant to 0. The method is more illustrative under an array of data and frequent observations.

For a quantitative assessment of worsening the indicator, the State Standard recommends establishing special patterns, but they are acceptable to assess imbalance in the technological process or discrepancy of product quality, when the assessed parameter variation is less than 10%.

Moreover, these patterns respond to deviations from a target downwards, which would mean “too high level of safety performance” for $K_{бп}$. Thereafter, the patterns are not relevant for the SPI, and an inclination of a graph curve may be a criterion. Similarly, to imbalance, when an inclination reaches 45^0 and greater, it is regarded that a process is out of control, and troubleshooting is required. When deviations are accidental at small angles, adjustment is sufficient. When the graph line is horizontal or has a negative inclination, the SPT is maintained, at least.

4. Prediction of the SPI

Prediction of the SPI in aviation activity has always been of great importance, which is also a controlling problem. Let us consider two prediction methods: the method founded on exponential data smoothing and the Holt’s method.

The method of exponential smoothing is employed to form a prediction for a single period ahead. The formula to employ the method from [20] in the agreed notation:

$$K_{r+1}^{п} = \alpha K_r^{ф} + (1-\alpha)\text{U}, \quad (5)$$

[3] The State Standard R ISO 7870-4-2013 Statistical Methods (2013). Checklists. Ch. 4. Checklists of cumulative sums. Moscow: Standartinform, 52 p. (in Russian)

Table 4

Actual data for 2022 and predicted values ($К_{БП}$) in 2023

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
$K_r^{ф}$	19.09	14.70	16.27	13.52	13.61	17.76	5.50	13.90	10.32	18.68	14.00	23.52
Actual data and the prediction for 2023. MAPE = 20,67%												
$K_r^{ф}$	10.97	17.72	11.66	20.87	23.39	16.44	13.10	16.47	14.22	11.74	15.03	17.78
$K_r^{п}$	*16.48*	*14.22*	*15.33*	*14.36*	*15.80*	*16.48*	*15.74*	*15.28*	*15.66*	*15.39*	*15.03*	*15.30*
ε_r	0.50	0.20	0.32	0.31	0.32	0.00	0.20	0.07	0.10	0.31	0.00	0.14

$K_r^{ф}$ – the actual value of the indicator; $K_{r+1}^{п}$ – the predicted value of the indicator; ε_r – the error

where $K_{r+1}^{п}$ – the predicted value of the indicator;

$K_r^{Ф}$ – the actual value of the indicator over the previous period;

α – the smoothing parameter;

U – the exponentially weighted average.

[20] recommends calculating the parameter $\alpha = \frac{2}{n+1}$, where n – the number of observations within a smoothing range. Let us conduct the prediction $К_{БП}$ for each month of 2023 taking into consideration data over 12 months of 2022. Therefore, while calculating the prediction by months of 2023, α will change from $\alpha = \frac{2}{12+1} = 0.167$ to $\alpha = \frac{2}{24+1} = 0.008$.

The parameter U is calculated as an average value of the previous period of observation, i.e., while calculating the prediction by months of 2023, U will also change from average over 12 months of 2022, when predicting $К_{БП}$ for January 2023, to average over 23 months, when predicting $К_{БП}$ for December 2023. Calculation data is summarized in Table 4. Each line calculates relative operational margins of the prediction $\boldsymbol{\varepsilon_r} = \left|\frac{K_r^{ф} - K_r^{п}}{K_r^{ф}}\right|$, which are used to calculate an average operational margin MAPE (*Mean Absolute Percentage Error* [21]):

$$MAPE = \frac{1}{n}\sum_1^n \varepsilon_r \cdot 100. \qquad (6)$$

The prediction by [20] is considered excellent under 10% > MAPE, good under 10% < MAPE < 20% and satisfactory under 20% < MAPE < 30%, i.e., the prediction is quite close to a good level. **Predicting a level of safety performance using the Holt's method** by [20] is carried out by means of exponential smoothing considering a trend.

Values of exponentially smoothed series $K_r^{пс}$ are calculated according to the formula

$$K_r^{пс} = \alpha K_{r-1}^{ф} + (1-\alpha)(K_{r-1}^{пс} - T_{r-1}), \qquad (7)$$

where T_{r-1} – the trend value over the previous period.

For the first period, let us assume $K_r^{п} = K_r^{ф}$, further, the calculation is conducted considering a trend:

$$T_r = \beta) + (1 - \beta T_{r-1},$$
$$K_r^{п} = K_{r-1}^{п} + T_r, \qquad (8)$$

where β – the coefficient of trend smoothing, α and β are selected within a range from 0 to 1.

Initially let us assign $\alpha = \beta = 0.5$. Calculation data is summarized in Table 5.

Prediction accuracy can be increased by the function MS Excel "Search for solution"[4]. Optimal fitting of coefficients α = 0.16 and β = 0,65 is provided, which enabled us to minimize a tar-

[4] Manual on the use of the "Search for solution" MS Excel function. microexcel.ru. Available at: https://microexcel.ru/funkcziya-poisk-resheniya/?ysclid=lqtb1wapdo508027718#poisk-resheniya-exc-1 (accessed: 11.03.2024).

Table 5

Initial prediction by the Holt method. MAPE = 20.64%

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
$K_r^{ф}$	10.97	17.72	11.66	20.87	23.39	16.44	13.10	16.47	14.22	11.74	15.03	17.78
$K_r^{пс}$	10.97	14.35	12.16	16.64	18.96	16.59	14.88	16.12	15.08	13.63	14.80	16.23
T_r	0.00	1.69	−0.25	2.12	2.22	−0.08	−0.89	0.17	−0.43	−0.94	0.11	0.77
$K_r^{п}$	10.97	10.97	16.03	11.91	18.75	21.17	16.52	13.99	16.30	14.65	12.68	14.92
$K_r^{ф} - K_r^{п}$	0.00	6.75	−4.37	8.96	4.64	−4.73	−3.42	2.48	−2.08	−2.91	2.35	2.86
ε_r	0.00	0.38	0.38	0.45	0.20	0.29	0.26	0.15	0.15	0.25	0.16	0.16

Table 6

Prediction by the Holt’s method with coefficient optimization. MAPE = 15.29%

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
$K_r^{ф}$	10.97	17.72	11.66	20.87	23.39	16.44	13.10	16.47	14.22	11.74	15.03	17.78
$K_r^{пс}$	10.97	12.03	11.39	13.02	13.81	13.50	13.35	13.89	13.67	13.39	13.81	14.26
T_r	0.00	0.69	−0.17	1.00	0.86	0.10	−0.06	0.33	−0.03	−0.19	0.20	0.36
$K_r^{п}$	10.97	10.97	12.72	11.22	14.02	14.68	13.60	13.29	14.22	13.64	13.20	14.01
$K_r^{ф} - K_r^{п}$	0.00	6.75	−1.06	9.65	9.37	1.76	−0.50	3.18	0.00	−1.90	1.83	3.77
ε_r	0.00	0.38	0.09	0.46	0.40	0.11	0.04	0.19	0.00	0.16	0.12	0.21

get function MAPE and obtain the prediction with MAPE = 15.29% (tab. 6).

Conclusion

The implementation of the controlling principles and philosophy into aviation activity will help enhance management efficiency and, in perspective, to generate an integrated system of production, safety, and quality management.

Calculation and monitoring of quantitative efficiency indicators to provide the SPI, as well as their prediction can be regarded as operative controlling considerations.

Currently, the SPIs applicable in ATS organizations do not reflect objectively a safety factor since:

1. Only aviation events are considered without assessing their severity;
2. Errors and violations of established rules and procedures by personnel, affecting safety performance which have not caused to an aviation event yet are not considered. In order to eradicate the defect, a balanced SPI has been developed relied on the expert survey with the assessment of the consistency of expert opinions.

The advantages of the SPI monitoring are shown by the methods of moving average and cumulative sums compared to direct monitoring.

Drawing on actual data of one of ATS organizations, the potential of short-term predicting the SPI, using the method of exponential smoothing and the Holt’s method, was demonstrated. It is shown that while calculating by the Holt’s method, minimization of a target function, by fitting optimal coefficients using the function MS Excel “Search for solution”, enables us to substantially improve the reliability of the prediction.

The proposed methods of calculation, monitoring and predicting SPI do not require additional software and expert knowledge, therefore, can be implemented in any aviation entity within the framework of its SMS.

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