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## CREATION OF A "SMART" OCCUPATIONAL SAFETY MANAGEMENT SYSTEM IN CIVIL AVIATION IN THE CONTEXT OF THE "SOCIETY 5.0" CONCEPT

**Abstract.** *This article examines current challenges in occupational safety and health in civil aviation in the Republic of Kazakhstan, including the growth of traffic volumes, increasing number of flights, and increasing complexity of technological processes. This demonstrates that traditional approaches that focus on monitoring violations and mitigating the consequences of incidents are limited in effectiveness and do not systematically prevent industrial risks. This article substantiates the need to transition to a "smart" occupational safety and health management system based on digitalization and intellectualization, the use of predictive analytics, automated monitoring tools, and the creation of a unified database for risk factor analysis. The proposed concept enables a shift from reactive to proactive occupational safety management, which reduces injury rates, improves the reliability of enterprise operations, and optimizes labor-resource utilization. It is emphasized that the implementation of a "smart" occupational safety and health system that complies with international standards will enhance the sustainability and competitiveness of Kazakhstan's aviation industry and will ensure its adaptation to global trends in technological development and increasing workload.*

**Keywords:** *occupational safety, civil aviation, digitalization, predictive analytics, intelligent monitoring, society 5.0.*

### Introduction.

Civil aviation is one of the most dynamic and high-tech sectors in the global economy, where occupational health and safety issues play a key role. The high intensity of aviation processes, complexity of technical systems, and high cost of error necessitate special attention to the development of effective occupational health and safety management mechanisms. Violations in this area can have consequences not only for the health and lives of workers but also for the safety of passengers, the environment, and the sustainability of the transportation system as a whole. Therefore, ensuring safe and healthy working conditions in civil aviation has become an integral part of the industry's strategic development [1]. Moreover, with the implementation of the "Society 5.0" concept, approaches to occupational health and safety management have changed significantly. Traditional control methods, based primarily on recording violations and consequences, provide proactive and predictive systems that utilize big data, artificial intelligence, and digital twins, enabling the real-time monitoring of worker health and the production

environment, predicting the likelihood of accidents, and developing targeted preventive measures [2].

In particular, the use of predictive analytics based on big data makes it possible to forecast the risks of occupational injuries; the implementation of intelligent monitoring systems ensures monitoring of the health and performance of personnel, promotes a more rational distribution of working time, reduces fatigue, and the automation of routine processes reduces the influence of human factors and the likelihood of errors [3]. Tools, such as wearable devices and cyber-physical systems, create the possibility of developing individualized models of worker health protection, taking into account their physiological characteristics and professional workload. This not only increases the sustainability of the functioning of aviation enterprises but also promotes the development of a safety culture, where each employee is considered an active participant in the system and not just an object of observation [4]. Moreover, electronic consultations and the introduction of telemedicine into practice are becoming accessible methods that provide prompt consultations to enterprise employees on-site. These advanced technologies allow enterprises to maximize employee engagement in the occupational health and safety system and reduce occupational diseases and injuries [5]. The integrated occupational safety system created in this way will allow airlines not only to comply with ICAO requirements, but also to fully adhere to the principles of "preventive safety," which emphasizes prevention rather than remediation.

Thus, the digitalization and intellectualization of the occupational health and safety management system within the framework of the development of the "Society 5.0" concept open up new prospects for improving occupational health and safety mechanisms in civil aviation, transforming it from a supporting function into a strategic factor in increasing the efficiency, competitiveness, and sustainability of the entire industry.

The goal of this article is to develop conceptual principles and practical recommendations for creating a "smart" occupational safety and health management system in civil aviation, integrated with digital technologies and consistent with the principles of the "Society 5.0" concept. To achieve this goal, the following objectives were formulated: to explore an industry-specific occupational safety and health management model in civil aviation in the Republic of Kazakhstan, as one of the most rapidly developing industries, and to explore ways to improve the effectiveness of occupational safety and health management in civil aviation enterprises.

#### **Literature review.**

An analysis of literary sources indicates that, in recent years, the problem of ensuring safe and healthy working conditions in civil aviation has acquired particular significance. This is due not only to the growth in transportation volumes and the increasing complexity of technical processes but also to the need to meet new requirements of sustainable development, where people and their safety occupy a central place [6]. Moreover, as Karakavuz and Gerede (2024) emphasize, ground-handling companies have the highest potential for industrial accidents in the air transportation sector, which leads to a significant increase in compensation costs for both companies and the state [7]. Therefore, the successful implementation of occupational health and safety management systems (OHSMS) plays an important role in the development of a safety culture among civil aviation personnel, ensuring the preservation of airline employees' health and consequently increasing their efficiency and productivity [8]. Consequently, improving the success of occupational health and safety management systems is of considerable importance in the organization of aviation personnel [9].

Thus, the analysis of scientific publications demonstrates significant progress towards digital transformation and implementation of intelligent technologies in occupational safety management. The combination of these approaches should be recognized as key development vectors that enable the creation of smart, adaptive, and transparent management systems, which is particularly relevant for highly sensitive industries, including civil aviation. Their symbiosis opens new horizons in the development of a modern safety concept, focusing on risk prediction, proactive

measures, and continuous process optimization, which, in turn, plays a decisive role in ensuring the operational reliability and long-term sustainability of the industry.

### Material and Methods.

The methodology chosen by the authors ensures the scientific rigour and validity of all stages of the study, from conceptualisation to the assessment of the practical potential of innovative solutions in the field of labour protection. The following materials were used for this study: data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan; the regulatory framework of the international (in particular, ICAO, ITF regulations, etc.) and national levels (in particular, legislative and regulatory acts of the Republic of Kazakhstan in the field of civil aviation), airline reports, etc.

### Results and their discussion.

Over the past decade, the Republic of Kazakhstan has been actively implementing reforms in the field of occupational safety and health aimed at transitioning to a risk-based model of occupational safety and health management. Over the years, international occupational safety standards have been ratified, labor and social legislation have been revised, and state control over compliance with safety requirements has been strengthened. Despite these measures, the expected significant improvement in working conditions has not been achieved. The main reasons for the persistent problematic situation are limited statistical data for certain types of economic activity, insufficiently informative monitoring of harmful working conditions, which does not ensure the systematic accumulation of information for the analysis and identification of cause-and-effect relationships between injuries and occupational diseases, and the absence of a clearly defined algorithm for assessing the effectiveness of occupational safety and health management models, both at the individual industry level and on a national scale [10].

To find effective solutions and develop recommendations for improving the occupational safety system, a study was conducted to examine the state of occupational safety and working conditions for personnel in civil aviation, which is one of the most dynamically developing sectors in the country.

The occupational safety management system in Kazakhstan's civil aviation was chosen as the focus of this study because Kazakhstan's air passenger and cargo transportation market is the most stable and fastest growing in the Central Asian region. According to the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 14.7 million passengers were transported by air in the country from January to December 2024 (Table 1), an increase of 10.6% from January to December 2023. Passenger turnover also increases accordingly. In 2024, it amounted to 28.3 billion passenger kilometers, 9.3% higher than the previous year's figure [11].

Table 1 – Dynamics of performance indicators of civil aviation in Kazakhstan during 2015-2024 [11]

Year s	Income, mln. tenge			Passenger transportation, thoun. pepole	Passenger turnover, mil. pass. kilom.	Transported cargo, baggage, and over- the-counter baggage, thoun. mil. tonns	Freight turnover, mil. tonn per kilomete r
	Total	Included					
		baggage	passenge rs				
2015	179556,6	4420,1	175136,5	5924,9	11138,6	17,0	42,44
2016	233590,9	5214,9	228376,0	6006,12	11073,0	18,1	42,99
2017	295584,6	6294,7	289289,9	7352,17	14384,2	22,4	53,33

2018	343284,3	7287,0	335997,3	7858,53	16176,7	29,1	55,67
2019	403018,2	8776,2	394242,0	8614,79	16940,3	25,1	54,2
2020	187696,3	11623,0	176073,3	5489,71	8335,0	24,2	56,2
2021	366308,9	17036,4	349272,5	9434,05	14815,7	34,0	81,68
2022	602049,6	13055,7	588993,9	10993,6	20109,3	24,5	54,44
2023	745128,6	13219,6	731909,0	13266,6	25898,5	23,8	53,7
2024	833535,6	15501,7	818033,9	14678,7	28275,7	27,88	65,7

According to the Civil Aviation Committee of the Republic of Kazakhstan, from 2015 to 2024, Kazakhstan's civil aviation demonstrated steady growth in key indicators: revenue, passenger traffic, passenger turnover, and cargo volume. The growth in the number of flights and volume of passenger and cargo operations is accompanied by the increasing complexity of technological processes and the increased intensity of employee work, making them more vulnerable to harmful and adverse factors. Under these conditions, the industry's effectiveness depends largely on a systematic approach to occupational safety, including monitoring, prevention, and adaptation of organizational and technical measures to the actual workload of workers.

To formulate informed management decisions and evaluate the effectiveness of the measures taken, it is necessary to rely on quantitative data from personnel engaged in harmful and hazardous working conditions. The analysis of such statistics allows us to identify trends in changes in the workforce, assess the impact of increased activity intensity on professional risks, and develop targeted measures to reduce injuries and occupational diseases. Therefore, we turn to the data in Table 2, which reflects the number of civil aviation workers in Kazakhstan employed under harmful and hazardous working conditions in the period 2015–2024, with details on employee categories, work schedules, and the nature of the impact of unfavorable factors.

Table 2 – Number of air transport workers employed in harmful and hazardous working conditions during 2015-2024, people [12]

Years	Average headcount of employees		Of these, those employed in harmful and hazardous working conditions				
	total	including workers	of which are employed on the	employed in conditions that do not meet sanitary and hygienic requirements	of which are working under the influence		
					increased levels of noise and vibration	increased dustiness and gas contamination of the air in the working area, exceeding the	unfavorable temperature conditions
2015	6756	3399	2052	712	723	31	74
2016	7054	3011	3043	1355	871	38	-
2017	7138	3393	3745	1476	989	47	95
2018	7385	3081	3373	2451	1379	59	-
2019	8011	3657	3945	3835	2871	51	70
2020	7480	2909	4646	2144	2080	31	98
2021	7748	2634	4285	2169	2136	34	98
2022	8557	3371	4723	3454	1978	33	93
2023	10346	2265	4086	1762	534	37	1533
2024	10946	2481	2638	2931	1182	6	-

Based on the data in Table 2, over the analyzed period, the number of air transport employees in Kazakhstan increased from 6,756 to 10,946, reflecting the industry's active development. However, along with employment growth, there were significant changes in the structure of the working conditions. For example, the number of employees employed in hazardous and dangerous conditions has decreased from 3,399 in 2015 to 2,481 in 2024, representing a decrease from more than half of the workforce (50.3%) to less than a quarter (22.7%). This trend indicates a gradual improvement in working conditions and more effective implementation of occupational safety measures despite the overall increase in transportation volumes and production workload.

The dynamics of the types of harmful factors show heterogeneity; in 2019, the number of workers exposed to noise, vibration, and dust peaked (up to 2,871 people); by 2024, these figures had decreased significantly, likely due to the renewal of the equipment fleet and improved sanitary and hygienic conditions. At the same time, in 2023, the number of workers working in unfavorable temperature conditions increased sharply (1,533 people), indicating the persistence of certain problem areas requiring additional protective measures.

An analysis of specific hazardous factors shows that the quantitative increase in the number of workers in the industry is accompanied by qualitative changes in the nature of the occupational risks. While the overall share of those employed under hazardous conditions decreases, the impact of certain high-intensity factors remains. This confirms that the development of civil aviation in Kazakhstan is accompanied not only by an increase in the volume of services but also by the need for a comprehensive improvement in the occupational safety system, from equipment modernization and the introduction of engineering safety measures to strengthen sanitary and hygienic standards and adapt work processes to the increasing workload.

However, an analysis of the number of workers engaged in hazardous and harmful conditions allows us not only to assess the scale of the impact of adverse factors on personnel but also to trace a direct link between the workload and the economic consequences for aviation enterprises. The increase in the number of employees working under conditions of increased noise, vibration, dust, or unfavorable temperatures, as well as the increase in the volume of operations performed, inevitably leads to the need for compensation and additional benefits. These payments are an important element of social protection for workers and simultaneously generate significant material costs for companies, reflecting the economic side of ensuring safe working conditions (Table 3).

Table 3 – Material costs for payment of compensation to air transport workers for work in harmful and unfavorable working conditions during 2015-2024, thousand tenge [13]

Years	Material consequences for the year, million tenge	Of these				
		additional vacations	shortened working hours	therapeutic and prophylactic nutrition	milk and equivalent food products	additional payments for harmful and other unfavorable working conditions
2015	864,8217	819,0372	-	-	2,2995	40,3910
2016	868,6869	815,7733	-	2,9711		
2017	679,7064	635,6126	-	-	-	-
2018	660,7980	660,7980	-	-	-	-
2019	875,3117	783,2996	-	3,1160	2,7957	86,1004
2020	792,2340	665,4046	-	-	1,7889	125,0399
2021	1175,5821	1108,2964	-	-	1,8277	65,4480
2022	1463,4418	1377,8559	-	0,0340	2,3304	81,2435

2023	1185,7963	1077,447 0	-	36,0	2,8301	105,4831
2024	2156,3163	1918,405 4	1188,6	-	5,2411	130,0061

From 2015 to 2024, as shown in Table 3, material costs for compensation to air transport workers showed an upward trend, from 864,800 tenge in 2015 to 2,156,300 tenge in 2024. The bulk of these costs are attributed to the provision of additional vacations, whose share of total compensation consistently exceeds 80–90%, reflecting legislative and social guarantees for employees.

The dynamics of payments for harmful and unfavorable working conditions (additional payments, therapeutic and preventive nutrition, milk, and equivalent products) vary because of the growing number of employees working in harmful conditions and changes in the compensation structure. For example, since 2019, there has been a significant increase in additional payments for work in unfavorable conditions, coinciding with increased exposure to occupational risks, including noise, vibration, and unfavorable temperatures. In 2024, a significant expense item for shortened working hours was recorded for the first time, indicating the need to implement additional measures to protect and improve working conditions.

Thus, we conclude that there is a certain relationship between working condition indicators and the costs of airlines providing guarantees stipulated by the Labor Code of the Republic of Kazakhstan. The degree of this relationship can be determined using key occupational safety indicators, namely, occupational diseases and injuries (Table 4).

Table 4 – Occupational safety indicators for civil aviation personnel of the Republic of Kazakhstan for 2015-2024

Years	Number of victims, people		Loss of Life Injury Frequency Rate (TIFR)	Fatal Injury Frequency Rate (FIFR)	Loss of working time, days		Trauma Injury Severity Rate (LTISR)	Overall injury rate	Lost Time Injury Rate (LTIFR)
	total (LTI)	including fatalities			total	including due to accidents			
2015	281	21	41,5927	3,108348	5164	5164	18,3772	2,2632	23,7753
2016	287	16	40,6861	2,268217	5618	5618	19,5749	2,0784	23,2571
2017	303	20	42,4489	2,801905	5535	1479	18,2673	2,3242	24,2648
2018	318	22	43,0603	2,979012	5948	5453	17,1478	2,5111	24,614
2019	312	17	38,9465	2,122082	6788	6386	20,4679	1,9028	22,2627
2020	455	17	60,8289	2,272727	4756	4360	9,58241	6,3479	25,5621
2021	472	17	60,9189	2,194115	5853	5731	12,1419	5,0172	18,2635
2022	127	8	14,8417	0,934907	4933	4843	38,1338	0,3891	8,48385
2023	161	17	15,1293	0,958394	4759	6843	19,1583	0,3389	12,6284
2024	175	15	14,7827	0,933442	4721	7278	17,8672	0,3401	11,1563

The occupational safety indicators for civil aviation personnel presented in Table 4 demonstrate a clear correlation with the scale of industry operations. As the number of workers and traffic volumes increased, fluctuations in the number of injured persons were observed: peak values were recorded from 2020 to 2021 (455–472 people), coinciding with increased workloads on personnel, an increase in the number of flights and passenger and cargo flows, and complications associated with the COVID-19 pandemic. During these years, the Tier 1 Injury Frequency Rate (TIFR) reached its maximum values of approximately 60.9, and the Lengthy

Injury Severity Rates (LTISR) also increased, indicating increased intensity and risk of work activities.

Since 2022, a significant reduction in all key injury indicators has been observed: the number of injuries has decreased to 127–175, the injury frequency rate has fallen to 14.8–15.1, and the severity rate and LTIFR have also decreased, demonstrating the positive impact of implementing occupational safety systems, upgrading equipment, improving workflow organization, and reducing exposure to hazardous and harmful factors. Moreover, the fatal injury rate remained relatively low throughout the study period, indicating the sustainability of measures to prevent the most serious incidents.

Thus, the analysis shows that the growth in personnel and transportation volumes directly impacts operational risks; increased workload and scale of operations lead to an increase in the frequency and severity of injuries, but systematic improvements in occupational safety can reduce these risks and ensure safe working conditions. The dynamics in recent years confirm the effectiveness of accident prevention measures and the need to further develop worker protection mechanisms as the volume of aviation services increases.

However, in the context of digitalization and intellectualization, implemented within the framework of the "Society 5.0" concept, it is becoming more practical to implement a "smart" occupational health and safety management system that combines automated data collection and analysis, predictive analytics, wearable sensors, digital twins of workers, and integration with corporate information systems of airlines. Such a system will enable the creation of a complete digital model of the production environment and personnel, where each employee and technological process is monitored in real time.

Using wearable sensors and medical devices, the system records workers' physiological indicators—fatigue level, cardiovascular activity, body temperature, stress responses, and parameters of exposure to external factors (noise, vibration, temperature, and dust). The data were automatically analyzed using artificial intelligence algorithms, enabling the identification of potential risks before incidents, predicting the likelihood of injuries and occupational diseases, and identifying the most vulnerable areas of production processes. Digital twins of workers and production facilities enable the simulation of various work scenarios, assessing the impact of changes in workload, shift patterns, operating modes, and weather conditions as well as optimizing work schedules, task allocation, and preventative measures. Integration with analytical platforms allows management to obtain visual reports, forecasts, and recommendations, fostering a proactive rather than reactive approach to safety.

Implementing such a system in civil aviation enterprises will not only reduce the number of accidents and occupational illnesses but also optimize compensation costs, improve labor quality, and enhance the overall performance of aviation personnel. Furthermore, the smart system will foster a safety culture in which every employee is involved in managing their own health and safety, while the enterprise will gain a tool for sustainable development and compliance with international ICAO standards.

### **Conclusion.**

The results of the study confirm that the rapid growth of air traffic volumes, the increasing number of flights, and the increasing complexity of technological processes in civil aviation significantly increase the workload of personnel and simultaneously increase the demand for safe working conditions. In such conditions, occupational safety and health (OSH) is becoming a critical element of the industry's sustainability, as any error or accident not only entails material and social consequences, but also undermines trust in the air transportation system at the national and international levels. Traditional approaches, focused primarily on monitoring violations and mitigating the consequences of incidents, demonstrate limited effectiveness as they fail to fully identify and prevent the root causes of operational risks. This is especially evident in the rapidly evolving aviation industry, where timely and predictive decision making is crucial.

In this context, the transition to a "smart" OSH management system is particularly urgent. This involves the digitalization and intellectualization of processes, integration of automated monitoring tools, use of predictive analytics, and development of a unified database for systematic risk analysis. Unlike traditional methods, this system not only records violations, but also proactively identifies potentially hazardous situations, predicts the likelihood of accidents and occupational diseases, and plans preventative measures based on the specifics of technological processes and the actual workload of workers. Implementing this approach enables a transition from reactive to proactive occupational safety management, which significantly reduces injury rates, optimizes labor resource allocation, reduces the economic costs associated with compensation and downtime, and strengthens employee confidence in the safety system.

Furthermore, the implementation of a "smart" occupational safety management system aligns with modern international trends and promotes the harmonization of national practices with global standards. This is particularly important for the aviation industry, which is deeply integrated into the global transportation system. This will not only improve the reliability and sustainability of airline operations, but also strengthen Kazakhstan's competitive position internationally.

Thus, the development of an intelligent model for occupational health and safety management is a strategic direction that ensures long-term operational reliability, increased personnel safety, and sustainable development of the industry in the context of increasing work intensity and technological modernization.

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### **АЗАМАТТЫҚ АВИАЦИЯДА «ҚОҒАМ 5.0» КОНЦЕПЦИЯСЫ АЯСЫНДА «ЗИЯТКЕРЛІК» ЕҢБЕК ҚАУІПСІЗДІГІН БАСҚАРУ ЖҮЙЕСІН ҚҰРУ**

*Аңдатпа.* Мақалада Қазақстан Республикасының азаматтық авиация саласында еңбек қауіпсіздігіне қатысты заманауи сын-қатерлер қарастырылады. Олар тасымал көлемінің өсуімен, рейстер санының артуымен және технологиялық үдерістердің күрделенуімен байланысты. Дәстүрлі тәсілдердің бұзушылықтарды бақылауға және оқиғалардың салдарын жоюға бағытталуы шектеулі тиімділікке ие екендігі және өндірістік тәуекелдердің жүйелі алдын алуын қамтамасыз етпейтіні көрсетілген. Цифрландыру мен интеллектуалдандыруға, предиктивті аналитикаға, автоматтандырылған мониторинг құралдарына және тәуекел факторларын талдау үшін бірыңғай деректер базасын құруға негізделген «зияткерлік» еңбек қауіпсіздігін басқару жүйесіне көшу қажеттілігі дәлелденеді. Ұсынылған тұжырымдама еңбек қауіпсіздігін реактивті басқарудан проактивті басқаруға көшуге мүмкіндік береді, бұл жарақаттану деңгейін төмендетуге, кәсіпорындардың сенімді жұмыс істеуін арттыруға және еңбек ресурстарын тиімді пайдалануды қамтамасыз етуге жағдай жасайды. «Зияткерлік» еңбек қауіпсіздігі жүйесін енгізу халықаралық стандарттарға сәйкес келетіні, Қазақстан авиация саласының орнықтылығын және бәсекеге қабілеттілігін арттыратыны, сондай-ақ оны технологиялық дамудың жаһандық үрдістеріне және еңбек қарқындылығының өсуіне бейімдейтіні ерекше атап өтіледі.

**Түйін сөздер:** еңбек қауіпсіздігі, азаматтық авиация, цифрландыру, болжамды талдау, зияткерлік мониторинг, қоғам 5.0.

### **СОЗДАНИЕ «УМНОЙ» СИСТЕМЫ УПРАВЛЕНИЯ ОХРАНОЙ ТРУДА В ГРАЖДАНСКОЙ АВИАЦИИ В КОНТЕКСТЕ КОНЦЕПЦИИ «ОБЩЕСТВО 5.0»**

*Аннотация.* В статье рассматриваются современные вызовы в сфере охраны труда в гражданской авиации Республики Казахстан, связанные с ростом объемов перевозок, увеличением числа рейсов и усложнением технологических процессов. Показано, что традиционные подходы, ориентированные на контроль нарушений и устранение последствий происшествий, обладают ограниченной эффективностью и не обеспечивают системного предупреждения производственных рисков. Обосновывается необходимость перехода к «умной» системе управления охраной труда, основанной на цифровизации и интеллектуализации, использовании предиктивной аналитики, автоматизированных средств мониторинга и создании единой базы данных для анализа факторов риска. Предлагаемая концепция позволяет перейти от реактивного к проактивному управлению безопасностью труда, что обеспечит снижение уровня травматизма, повышение надежности функционирования предприятий и оптимизации использования трудовых ресурсов. Подчеркивается, что внедрение «умной» системы охраны труда соответствует международным стандартам, усилит устойчивость и конкурентоспособность авиационной отрасли Казахстана, а также обеспечит ее адаптацию к глобальным тенденциям технологического развития и росту интенсивности работы.

**Ключевые слова:** безопасность труда, гражданская авиация, цифровизация, прогнозная аналитика, интеллектуальный мониторинг, общество 5.0.

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