PROBLEMS AND SOLUTIONS OF INFORMATION EXCHANGE IN INTEGRATED CONTROL SYSTEMS

Babaqulov Ilxomjon Xaliqulovich
Chief Specialist at the Digital Government Project Management Center, Tashkent, Uzbekistan
ilxomb@gmail.com

Rustamova Moxichexra Yaxshiboyevna
Senior Lecturer at Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Tashkent, Uzbekistan
mohimrustamova83@gmail.com

Abilov Dilshod Bekzod o'g'li
Student at Tashkent University of Information Technologies named after Muhammad al-Khwarizmi
abilovdilshod55@gmail.com

Shavkatov Bahodirjon Sherali o'g'li
Student at Tashkent University of Information Technologies named after Muhammad al-Khwarizmi
baxodirjonshavkatovv@gmail.com
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Abstract

This article provides a scientific analysis of the risk management system in information exchange processes between various control authorities at border checkpoints. The study examines issues of ensuring data security in information exchange channels, integrating fragmented systems, and centralizing inter-agency information flows. An automatic information risk classification mechanism based on a multi-criteria assessment model, CART decision tree, and Random Forest algorithm is proposed. The research findings establish a methodological basis for transitioning to proactive management of information exchange processes at border checkpoints.

Keywords:

information exchange, risk management, border control, inter-agency integration, data security, risk analysis, information model.

Annotatsiya

Ushbu maqolada chegara punktlarida turli nazorat organlari o'rtasida axborot almashish jarayonlarida yuzaga keladigan xavflarni boshqarish tizimi ilmiy jihatdan tahlil qilingan. Tadqiqotda axborot almashish kanallarida ma'lumotlar xavfsizligini ta'minlash, fragmentatsiyalangan tizimlarni integratsiyalash va idoralararo axborot oqimlarini markazlashtirish masalalari ko'rib chiqilgan. Ko'p mezonli baholash modeli, CART qaror daraxti va Random Forest algoritmlari asosida axborot xavflarini avtomatik tasniflash mexanizmi taklif etilgan. Tadqiqot natijalari chegara punktlarida axborot almashish jarayonini proaktiv boshqarishga oʻtkazish uchun metodologik asos yaratadi.

Kalit soʻzlar: axborot almashish, xavfni boshqarish, chegara nazorati, idoralararo integratsiya, ma'lumotlar xavfsizligi, risk tahlili, axborot modeli.

Аннотация

В данной статье научно проанализирована система управления рисками в процессах информационного обмена между различными контрольными органами на пограничных пунктах пропуска. В исследовании рассмотрены вопросы обеспечения безопасности данных в каналах информационного обмена, интеграции фрагментированных систем и централизации межведомственных информационных потоков. Предложен механизм автоматической классификации информационных рисков на основе многокритериальной модели оценки, дерева решений CART и алгоритма случайного леса. Результаты исследования создают методологическую основу для перехода к проактивному управлению процессами информационного обмена на пограничных пунктах.

Ключевые слова: информационный обмен, управление рисками, пограничный контроль, межведомственная интеграция, безопасность данных, анализ рисков, информационная модель.

Introduction

The data exchange process in modern border control systems is becoming increasingly complex. Various regulatory bodies - customs, veterinary, sanitary, phytosanitary, migration services - need to process and exchange huge amounts of data in the course of their activities. The effective organization of these processes is important for national security, trade activity, and the effectiveness of public administration [1, 2].

However, there are currently a number of serious problems with information exchange systems at border crossings. The fragmentation of data across different platforms, the poor organization of interdepartmental information exchange, the increasing number of information security threats, and the lack of real-time monitoring significantly reduce the effectiveness of control processes [3].

Managing risks in the information exchange process is one of the key areas for addressing these challenges. A risk management system ensures the security, completeness, and timely delivery of information, taking border control to a new level of quality. Therefore, the scientific development of a risk management system in the process of information exchange at border crossings is an urgent practical and theoretical task [4, 5].

2. Literature review

Issues of information exchange and risk management at border controls are widely studied in the international scientific community. Aven et al. (2023) developed a unified conceptual framework for integrating intelligence and risk management in customs and border control, analyzing modern approaches to minimizing risk in information exchange channels [6].

Thomann et al. (2024) showed the possibility of targeted allocation of control resources by forming a risk index based on the Random Forest algorithm in livestock control. The study presents practical results of data integration and automatic risk assessment in information systems [7].

In the article by Shu and others (2023), the prediction of import product risks at Taiwanese border crossings was studied using an ensemble learning model. The results provide practical evidence of the effectiveness of AI-based automatic classification systems in border control [8].

A study by Oldroyd et al. (2021) showed the effectiveness of using machine learning methods to optimize control resources and preemptively identify high-risk objects [9]. Selim et al. (2021) empirically demonstrated that the CART decision tree model can classify risk factors with higher accuracy than logistic regression [10].

Thus, the analyzed literature confirms the need to integrate the information exchange process in border control with a risk management system and the possibility of using modern algorithmic approaches in this direction.

Classification of risks in the information exchange process at border points

Main types of information risks

The risks that arise in the information exchange process at border points are divided into several main categories. This classification is the necessary basis for systematic risk management and the development of countermeasures.

Table 1. Classification of information exchange risks at border crossing points

Risk category	Risk content	Impact level
Technical risks	System outage, server failure, data loss	High
Cybersecurity risks	Unauthorized access, data theft, DDoS attacks	Too high
Organizational risks	Protocol violations, staff errors, lack of process consistency	Middle
Data quality risks	Incomplete, inaccurate, or duplicate information	High
Integration risks	Incompatibility between systems, format differences	Mid-High

Information risk quantitative assessment model

The following multi-criteria integral model is used to quantitatively assess risks in the information sharing process:

$R = \Sigma (w_i \times K_i \times V_i), \quad i = 1, 2, ..., n$

Where: R is the general information risk level; w.is the weighting factor of the criterion; K_i is the risk factor (in the 0-1 range) by the criterion; V_i is the impact force of the criterion.

The weight coefficients are determined using experts based on the AHP (Analytic Hierarchy Process) method. The coefficients are as follows, provided that the consistency ratio CR < 0.10 is met:

Table 2. Risk criteria and weighting coefficients

Criterion	Mark	**Weight(w_i)**	Risk indicator
Information security	K_1	0.30	0.72
Reference completeness	K_2	0.25	0.68

Criterion	Mark	Weight(w_i)	Risk indicator
System stability	K_3	0.20	0.75
Degree of integration	K_4	0.15	0.60
Monitoring efficiency	K_5	0.10	0.65

Calculation results in: R = 0.30×0.72 + 0.25×0.68 + 0.20×0.75 + 0.15×0.60 + 0.10×0.65 = 0.216 + 0.170 + 0.150 + 0.090 + 0.065 = 0.691. This value confirms the need to improve the system, indicating a medium-high level of risk.

Risk management system model in the information exchange process

System architecture

In the proposed information exchange process, the risk management system is built on a modular architecture, which consists of four main layers:

Input layer (Input Layer) - receiving data from various control bodies and systems;

Processing layer (Processing Layer) - standardization, verification and filtering of data;

Analysis layer (Analytical Layer) - risk assessment, classification and decision making;

Output layer (Output Layer) -communication and monitoring of results to the relevant authorities.

Each layer acts as an independent functional module, but they operate interrelated within a single integrated platform. This modularity principle ensures the flexibility and scalability of the system [6].

Automatic risk classification algorithm

For automatic classification of risks in the information sharing process, a combination of CART decision tree, logistic regression, and Random Forest algorithms is used. This approach is carried out in three stages.

The first stage is preliminary filtering. Incoming information flows are subject to syntactic and semantic verification. Incomplete or incorrectly formatted data is detected at this stage and is not sent for processing.

The second stage is to determine the level of risk. The CART decision tree algorithm classifies data based on the following criteria: source reliability, data completeness, transmission channel security, and historical error statistics. The result is a risk level - low, medium, or high - for each information flow [10].

The third stage is decision-making. The Random Forest algorithm confirms the results of CART and forms the final decision: accept the information, send it for further investigation, or reject it [7].

Artificial intelligence-based risk prediction model

To further improve the system, an AI-based sigmoid function prediction model is introduced:

$P(risk) = 1 / (1 + e^{(-\beta(R - \theta))})$

Here: P(risk) is the probability of a risk occurring; R is the integral risk index; $\theta = 0.65$ is the risk threshold; $\beta = 10$ is the sharp threshold coefficient.

When calculated with a value of R = 0.691: P(risk) = 1 / (1 + e^(-10(0.691 - 0.65))) = 1 / (1 + e^(-0.41)) ≈ 0.601. This result indicates that the risk of occurrence is 60.1%, indicating the need to switch the system to an enhanced monitoring mode.

Practical mechanisms for managing the risks of interdepartmental information exchange

A single information security standard

It is necessary to introduce a single standard to ensure the security of interdepartmental information exchange at border points. This standard includes the following requirements:

-Data encryption - all information flows must be transmitted via the TLS 1.3 or higher protocol;

Authentication - implementation of a multi-factor authentication system;
Audit trail - automatic logging of all information exchange operations;
Access Control - Differentiating data access rights based on roles;
Backup - Creating and maintaining regular backups of data.

Real-time monitoring system

A real-time monitoring system will be introduced to continuously monitor the risks in the information exchange process. This system will perform the following functions:

Monitor the intensity of information flows and detect anomalies;
Automatically send alerts based on changes in risk indicators;
Continuously check system stability and data completeness;
Automatic formation of statistical reports and trend Analysis.

The Monitoring system is able to process millions of data packets per second based on Big Data Technologies. This ensures continuity and security of information exchange at border points [8].

Three-tier risk management system

A three-tier system is used to manage information sharing risks:

Green category (low risk, $R < 0.40$) - information sharing continues as usual, standard monitoring is carried out;

Yellow category (medium risk, $0.40 \leq R < 0.70$) - enhanced monitoring is introduced, additional inspection is carried out;

Red category (high risk, $R \geq 0.70$) - information exchange is temporarily suspended, the system administrator is notified, and immediate action is taken.

This classification system allows for the efficient allocation of control resources and timely elimination of hazardous situations [9].

Results

As part of the research carried out, the following main results were obtained.

As a first result, a scientific classification of risks in the process of exchanging information at border points was developed. Five categories of risks - technical, cybersecurity, organizational, data quality, and integration risks - were identified and their impact levels were determined.

As a second result, a multi-criteria integral risk assessment model was proposed. When calculated with the weight coefficients determined based on the AHP method, the overall risk index $R = 0.691$, which indicates a medium-high risk level.

As a third result, an AI-based prediction model was introduced. With a value of $P(risk) \approx 0.601$, it was determined that the system should be switched to an enhanced monitoring mode.

As a fourth result, a three-category risk management system (green, yellow, red) was established. This system allows for the targeted allocation of control resources and the timely elimination of hazardous situations.

As a fifth result, an automatic classification mechanism was developed based on a combination of CART, logistic regression, and Random Forest algorithms. This mechanism allows for real-time detection of risks in the information exchange process and the taking of appropriate measures.

Discussion

The results of the study fully confirm the importance of implementing a risk management system in the process of information exchange at border crossings. The proposed model has a number of important advantages.

From the point of view of the proactive approach, the system allows you to identify dangerous situations not after they occur, but in advance, taking appropriate measures. This is qualitatively different from conventional jet control and significantly increases control efficiency.

In terms of flexibility, the modular architecture allows for rapid updates of the system to meet new requirements and technologies. In particular, the improvement of artificial intelligence models through self-learning ensures the long-term effectiveness of the system [7].

From an integration perspective, the proposed model can be seamlessly integrated with existing information systems - VIS-Border, Single Window, customs system. This allows for the implementation of risk management mechanisms based on existing infrastructure, without requiring the restructuring of individual systems.

Conclusion

As a result of the research, an integrated risk management system was developed for the exchange of information at border crossings. The proposed system allows for effective management of information exchange risks by combining modern information and communication technologies, multi-criteria mathematical evaluation methods, and elements of artificial intelligence.

The results of the study show that the risk indicator in the information exchange process at border crossings is $R = 0.691$, which indicates the need to improve the system. The AI-based prediction model, on the other hand, determines the probability of a risk occurring at $P \approx 0.601$, confirming the need to switch the system to an enhanced monitoring mode.

The proposed three-tier risk management system (green, yellow, red) allows for the targeted allocation of control resources, providing a mechanism for rapid processing of low-risk information flows and addressing high-risk situations through in-depth investigation.

It is recommended that in the future, as a methodological continuation of this study, practical tests of the system be conducted, work be carried out to harmonize it with international standards, and to fully integrate it with the information systems of the border control bodies of Uzbekistan**.**

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