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# DECISION SUPPORT MODEL FOR INTELLECTUAL PROPERTY MANAGEMENT

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This article examines the pressing issue of improving the effectiveness of decision support in intellectual property management. A well-founded definition of the term "decision support" is provided in the context of intellectual property management using artificial intelligence technologies. An original decision support model for managing intellectual property assets in government agencies is presented, taking into account the basic stages of intellectual property management and the requirements specific to public administration. The developed model formalizes the procedure for selecting and combining intelligent algorithms from a variety of those acceptable for specific business conditions, thereby improving the validity of decisions, including in the presence of incomplete data. The methodological foundation for the developed algorithms includes graph neural networks with a knowledge graph-based model and the GAT algorithm, genetic programming and particle swarm methods, a gradient boosting algorithm combined with BERT contextual embeddings, and the K-means method with contrastive loss.

*Keywords: management efficiency; information system; intellectual property; decision support; machine learning.*

## Introduction

The modern knowledge economy is characterized by the growing role of intellectual property as key assets determining technological leadership and the competitiveness of a country's economy [1]. At the same time, accelerating scientific and technological progress, the globalization of the knowledge economy, and the growing role of intangible assets in ensuring national defense and security require improved mechanisms and tools for intellectual property management. Traditional methods, relying on experts and classical regulatory procedures, face a number of systemic problems. Let's consider these in more detail.

1. Information overload. The number of patent applications and notifications from organizations identifying intellectual property capable of legal protection is growing exponentially, making manual analysis and detection of duplications (illegal borrowings) virtually impossible.

2. Difficulty in detecting violations. Illegal borrowings take complex forms (structural plagiarism, schemes involving "ghost authors", and others), for which textual similarity alone is not sufficient.

3. Subjectivity in decision making. The formation of patent portfolios and the assessment of the commercial potential of intellectual property are often based on the subjective experience of individual specialists, which can lead to suboptimal decisions in terms of the return-risk-budget balance.

4. High transaction costs and security risks. Traditional database and registry management processes, both at the departmental level and within organizations, are labor-intensive and associated with the risk of confidential information leakage.

Therefore, the solution to these problems lies in the digital transformation of decision support processes for intellectual property management, which underpins the relevance of this study.

It should also be noted that most decision support models focus on the tasks of selecting decision options under conditions of stochastic uncertainty or ambiguity [2], often ignoring the specific risk of working with deliberately distorted data, which is typical in the field of intellectual property management. Moreover, in such models, information security elements are typically considered in isolation – as secondary tasks of ensuring data confidentiality, integrity, and availability [3], rather than as an integral factor influencing the effectiveness of the decision-making process itself. Thus, there is a gap in the field of comprehensive decision support modeling that simultaneously considers decision performance targets and constraints associated with the reliability of source data in the face of real-world threats.

The purpose of this study is to formulate the problem and develop a formalized decision support model for intellectual property management that ensures the required effectiveness of management decisions in the face of the risk of working with false and incomplete data.

## 1. The Essence of Decision Support in the Intellectual Property Management System

Decision-making is a specific activity aimed at finding the optimal way to achieve a given goal [4]. The decision maker plays a key role in this process. Typically, this role is played by a manager or a group of subject-matter-competent specialists with the relevant knowledge and experience, the necessary authority to make a decision, and the responsibility for implementing the decision. However, with the increasing complexity, volume, and intensity of information flows, and the simultaneous reduction in decision-making time, ensuring highly effective decision support becomes a key task.

The concept of decision support takes on a special role in the context of automated management and information support for decision-making processes by authorized officials, known as decision makers. In accordance with GOST R 56862-2020, a separate category of artificial intelligence systems-decision-making (support) systems – is distinguished based on control loop functions.

Currently, federal regulations do not provide a formal definition for the term “decision support”. However, a number of state standards provide applied definitions related to relevant fields of knowledge, providing insight into the nature of decision support and the mechanisms for its implementation. For example, GOST R 71671-2024, which establishes the fundamental principles of medical decision support systems using artificial intelligence technologies, introduces definitions for the terms “medical decision support system” and “medical decision support system algorithm.” However, these definitions do not take into account the specific activities of federal executive bodies, where decision support is carried out based on large volumes of heterogeneous data, including confidential data. In this case, the place and role of the information technology infrastructure that enables the collection, storage, and processing of such data in various operating modes cannot be ignored. To simplify terminology, in this paper, the set of decision support software tools and the technical means that provide such software tools with access to specialized information resources will be referred to as a computer-automated system.

Based on the definitions of the above concepts, we introduce definitions for the terms "intellectual property management decision support system" and "intellectual property management decision support system algorithm". By "intellectual property management decision support system", the author defines it as a computer-based automated system that, through the processing and interpretation of collected information based on algorithms, supports the decision-making of authorized officials at all stages of intellectual property rights management in order to reduce errors and improve the quality of intellectual property tasks and functions. Therefore, in accordance with GOST 33707-2016, an algorithm for an intellectual property management decision support system should be understood as a finitely ordered set of precisely defined rules for solving a specific problem in the intellectual property management decision support system. It should be noted that an algorithm can be represented by a machine learning model, a mathematical model or formula, a sequence of instructions for processing input data, or another software implementation.

Given the terms and definitions discussed in this article, intellectual property management decision support will be understood as a process implemented using specialized software that, by processing and interpreting collected information based on specific algorithms, assists authorized officials in making decisions at all stages of intellectual property rights management.

## 2. Decision Support Model for Intellectual Property Management

According to W.R. Ashby's law of requisite variety, the diversity of a management system (knowledge of problem-solving methods) should exceed or at least match the diversity (complexity) of the managed object. Given the objectively present increase in the complexity of the decision-making support process for intellectual property management, in particular due to the increased volume and intensity of information flows while simultaneously reducing the time required for decision-making, improving the quality of management decisions is possible through the use of specialized systems, as well as decision support models and algorithms [5].

Based on the above, for the high-quality development of a decision-making support model for intellectual property management, we will consider and describe the initial data, which represents a set of theoretical foundations of the decision-making support methodology for intellectual property management, mathematical support, and software tools aimed at improving the efficiency of decision-making, the security of information circulating in the decision-making support system, and the validity of decisions.

Let the decision-making support process be defined by a vector of parameters of the technical characteristics of information system $B$, including the specified requirements for the information support for decision-making in intellectual property management. The configuration of the information security system to counteract information security threats $Z$ is specified by a vector of parameters of expected security threats and vulnerabilities [6].

The vector of target characteristics (direction) of decisions $S$ includes specified characteristics for decision-making efficiency, validity, consistency, and risk-orientation. In the decision support process, specialized algorithms $A_1, A_2, \dots, A_n$ are used depending on the specified parameters, forming set $A$. Moreover, each $i$-th algorithm from set $A$ has parameters aimed at implementing a particular task (function) of intellectual property rights management [7] $I_i, I = 1, 2, \dots, n$, where $n$ is the total number of permissible algorithms used in the decision support system to implement a specific task or function. The primary criterion for selecting a particular algorithm or combination of algorithms is ensuring the required quality of decision support $P_{\text{ppr}}$, subject to an acceptable probability of false data regarding the ownership of the assigned right to a particular result $P_{\text{ld}}\colon P_{\text{ld}} \leq {P_{\text{ld}}}^{\max}$, where ${P_{\text{ld}}}^{\max}$ is the specified maximum permissible value of data falsity, taking into account both the factor of unregulated rights to individual results and the factor of targeted malicious influence in the implementation of information security threats.

Under such conditions, the effectiveness of decision support will be determined by the probability of selecting the best solution option $P_{\text{ppr}}$ under the given conditions, including possible information security threats. As a function of the parameters of the initial data when using the $i$-th algorithm from set $A$, it is determined in accordance with the expression:

$$P_{\text{ppr}} = P_{\text{ppr}}[B, Z, S, A_i(I_i), P_{\text{ld}}],$$

where $B$ are the parameters of the technical characteristics of the information system; $Z$ is the configuration of the information security system to counter threats to information security; $S$ are the target characteristics (focus) of the decisions made; $A_i(I_i)$ are specialized decision support algorithms with specified parameters; $P_{\text{ld}}$ is the acceptable value of the probability of false data on the ownership of the assigned right to a particular intellectual property object.

The presented dependence takes into account the relationship between the characteristics of information processing and the required conditions for the effectiveness of decision support based on them $P_{\text{ppr}}$ and the processing of false data $P_{\text{ld}}$ [8]. The probability that the information system will consider false data in the decision support process is itself a function of the initial data parameters:

$$P_{\text{ld}} = P_{\text{ld}}[B, Z, A_i(I_i)].$$

The initial value $P_{\text{ld}}$ is initially specified, and after selecting the system's operating algorithms for specific conditions that ensure a maximum or specified probability of determining the best solution $P_{\text{ppr}}$, the probability of false data achievable with its use $P_{\text{ld}}$ is calculated and the fulfillment of the conditions $P_{\text{ld}} \leq {P_{\text{ld}}}^{\max}$ is checked. If the condition is not met, then the selection of operating algorithms is repeated, and the solution to the problem is the selection of an algorithm that meets the requirements for ensuring the maximum specified efficiency value under the given conditions. Thus, the solution to the problem is to select from a set of algorithms $A$ several of their combinations $A_i$, characterized by sets of parameters $I_i$, which ensure the required value of the probability of selecting the best solution option ${P_{\text{ppr}}}^{\text{tr}}$ under conditions where the initial data may be false or incomplete. Moreover, depending on the individual conditions of the problem, the solution is not unique, and combinations from the set of algorithms $A$ can be selected from a subset of admissible algorithms $\{A_i(I_i^*)\}$, satisfying the condition:

$$\{A_i(I_i^*)\}: P_{\text{ppr}}[B, Z, S, A_i(I_i), P_{\text{ld}}] \ \geq \ P_{\text{ppr}}{}^{\text{tr}}, A_i \in A, i \ = \ 1, 2, \ldots n,$$

under the established constraints $P_{\text{ld}}[B, Z, A_i(I_i)] \leq P_{\text{ld}}{}^{\max}$.

## 3. Algorithm for Implementing a Decision Support Model for Intellectual Property Management

The solution to the stated research problem consists of selecting from a set of algorithms $A$ those algorithms (or their combinations) $A_i$ that are characterized by sets of parameters $I_i{}^*$ and ensure the fulfillment of two conditions [9, 10]:

1. Ensuring the required efficiency – the probability of choosing the best solution must be no lower than a certain required (or maximum possible) threshold value $P_{\text{ppr}}{}^{\text{tr}}$.
2. Compliance with the reliability constraint – the probability of taking into account false data must not exceed the specified maximum permissible level $P_{\text{ld}}{}^{\max}$.

Formally, the solution to the problem is a subset of admissible algorithms $\{A_i(I_i^*)\}$ that satisfy the condition: $\{A_i(I_i^*)\}: P_{\text{ppr}}[B, Z, S, A_i(I_i), P_{\text{ld}}] \ \geq \ P_{\text{ppr}}{}^{\text{tr}}, A_i \in A, i = 1, 2, \ldots n$, subject to the established constraint: $P_{\text{ld}}[B, Z, A_i(I_i)] \leq P_{\text{ld}}{}^{\max}$.

Solving the problem is an iterative process, since the value of $P_{\text{ld}}$ used in calculating $P_{\text{ppr}}$ itself depends on the chosen algorithm. Thus, the following algorithm can be represented.

Step 1. Initialization. The initial vectors $B$, $Z$, and $S$ are specified, along with the target $P_{\text{ppr}}{}^{\text{tr}}$ and the constraint $P_{\text{ld}}{}^{\max}$.

Step 2. Initial Assessment. The initial, "naive" value of $P_{\text{ld}}{}^0$ is specified based on expert assessment.

Step 3. The algorithm selection cycle, in which:

1. For each algorithm $A_i$ from set $A$, the predicted performance value $P_{\text{ppr}}{}^i$ is calculated using the current value of $P_{\text{ld}}$;
2. For each algorithm $A_i$, the achievable probability of exposure to false data $P_{\text{ld}}{}^i$ is calculated;
3. A list of candidate algorithms is generated for which the constraint $P_{\text{ld}}{}^i \leq P_{\text{ld}}{}^{\max}$ is satisfied;
4. Algorithms (or combinations thereof) for which the $P_{\text{ppr}}{}^i$ value is maximum or satisfies the condition $P_{\text{ppr}}{}^i \geq P_{\text{ppr}}{}^{\text{tr}}$ are selected from the candidate list.

Step 4. Verification and iteration are performed in the following order. If the calculated value of $P_{\text{ld}}{}^i$ for the selected candidate algorithm differs significantly from the value of $P_{\text{ld}}$ used in point 1) of step 3, the calculation of $P_{\text{ppr}}{}^i$ is refined with the new value of $P_{\text{ld}}{}^i$. Steps 3–4 are repeated until an algorithm is found for which the $P_{\text{ppr}}{}^i$ and $P_{\text{ld}}{}^i$ values stabilize and satisfy the required conditions.

Step 5. Solution output. The solution to the problem is the found algorithm $A_i$ (or set of algorithms) with parameters $I_i{}^{**}$.

The flowchart of the algorithm under consideration is shown in Figure 1. The presented algorithm takes into account the relationship between decision-making efficiency and the reliability of initial data, ensuring a balanced selection of support tools that is consistent with modern intelligent approaches to decision support [11].

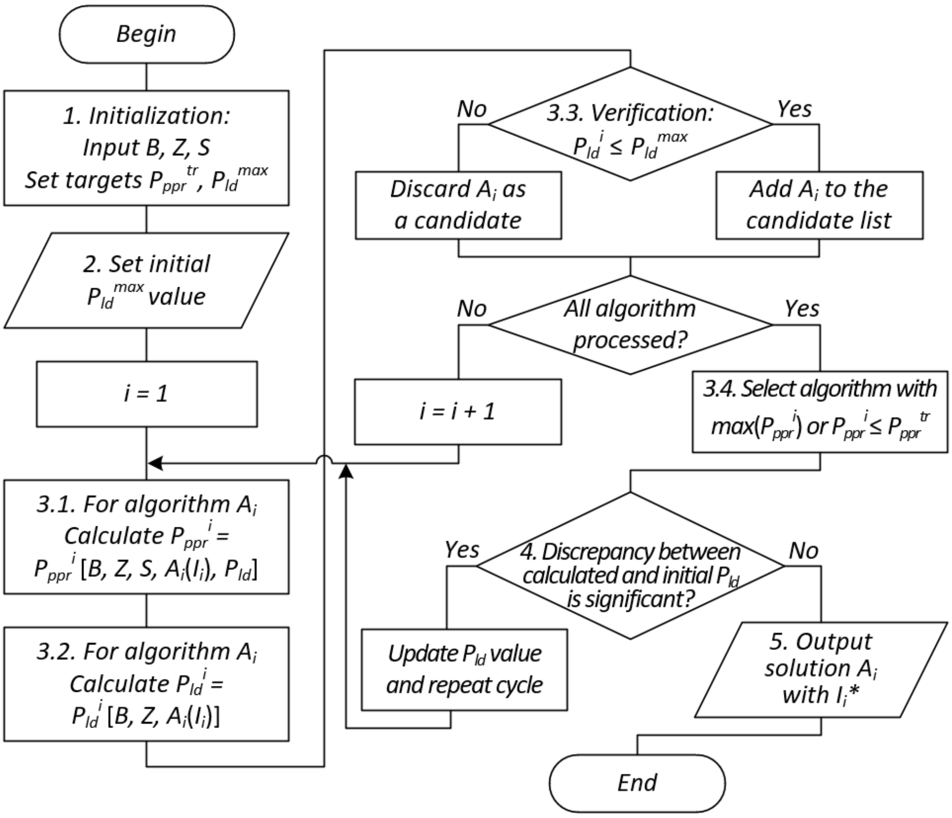


**Fig. 1**. Flowchart of the algorithm for implementing a decision support model for intellectual property management

## 4. Conclusions on the Main Results of the Study

The proposed decision support model for intellectual property management is a practical implementation of W. R. Ashby's law of requisite variety. The set of algorithms $A$ represents the diversity of the control system. The complexity of the controlled object (the decision support process under threats and false data) is described by a combination of vectors $B$, $Z$ and $S$, along with the constraint $P_{\text{ld}}$. The problem of selecting the optimal $A_i$ from set $A$ generally represents a control process in which the control system utilizes its internal diversity to counter the diversity of the external environment (the complexity of the controlled object). Thus, the model ensures the fulfillment of W. R. Ashby's condition through the use of a wide range of adaptable algorithms [12].

Unlike models focused solely on maximizing decision utility, the model under consideration explicitly includes the factor of data reliability as a hard constraint. This brings it closer to reliability and robustness problems in the specific context of information security [13, 14]. Furthermore, the model allows for the consideration of substantive characteristics of decisions $S$, such as validity and risk-orientation, allowing for a more adequate description of real-world intellectual property management processes [6].

Despite this, the proposed model has several limitations. These include the complexity of function evaluation, which means that estimating the main functions $P_{\text{ppr}}(\ldots)$ and $P_{\text{ld}}(\ldots)$ can be a non-trivial task and require extensive simulation modeling, statistical accumulation, or expert parameterization. Furthermore, the discrete nature of the algorithm set necessitates the model selecting the required algorithms from a finite set $A$, while some parameters $I_i$ may be continuous. However, it should be noted that the second limitation can be overcome by switching to optimization directly over the parameter space $I$.

### 4.1. Conclusion

The key result of this work is a developed model in which the effectiveness of decision support $P_{\text{ppr}}$ is represented as a function of information system parameters, security threats, target decision characteristics, and the algorithms used. The optimality criterion is ensuring the required level of effectiveness while strictly adhering to the constraint on the permissible probability of false data.

This model is of high practical significance, as it inherently provides for modularity and the ability to select various algorithms depending on the context. It enables a transition from intuitive selection of work methods to a substantiated one based on quantitative assessments of effectiveness and risks. It also integrates security issues directly into the decision-making process, enabling an assessment of how certain protective measures impact the overall effectiveness of management decisions.

Implementation of the developed approaches and solutions in the practice of executive authorities will systematically improve the quality, validity, and security of management decisions in the field of intellectual property management.

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# МОДЕЛЬ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ ПО УПРАВЛЕНИЮ ИНТЕЛЛЕКТУАЛЬНОЙ СОБСТВЕННОСТЬЮ

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В статье рассматривается актуальная проблема повышения эффективности поддержки принятия решений при управлении интеллектуальной собственностью. Дано обоснованное авторское определение термину “поддержка принятия решений” в контексте управления интеллектуальной собственностью с применением технологий искусственного интеллекта. Представлена оригинальная модель поддержки принятия решений по управлению результатами интеллектуальной деятельности в органах государственной власти, учитывающая базовые этапы управления интеллектуальной собственностью и специфические для государственного управления требования. Разработанная модель позволяет формализовать процедуру выбора и комбинирования интеллектуальных алгоритмов из множества допустимых для конкретных условий деятельности, что обеспечивает повышение обоснованности принимаемых решений, в том числе в условиях неполных данных. При этом в качестве методологической основы для разработанных алгоритмов выступают графовые нейронные сети с моделью на основе графа знаний и алгоритма GAT, методы генетического программирования и роя частиц, алгоритм градиентного бустинга в сочетании с контекстными эмбеддингами BERT и методом K-средних с контрастивной потерей.

*Ключевые слова: эффективность управления; информационная система; интеллектуальная собственность; поддержка принятия решений; машинное обучение.*

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