Development of a model of coordination strategies for decision-making in hierarchical technogenic systems

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Abstract
This paper aims to develop a coordination-control model for hierarchical technogenic systems that strengthens goal alignment, enhances stability of control processes, and ensures resilient decision-making under uncertainty and cyber-related risks. The proposed approach integrates procedures of goal alignment, hierarchical coordination of local strategies, and cognitive assessment of operators into a unified decision-support framework. The methodology includes formal modelling of the state and target spaces, construction of an objective function for coordination, and expert-based evaluation of operator characteristics using a modified Delphi method. The model is validated through a simulated crisis scenario reflecting real industrial conditions. The model enables structured generation of coordination strategies in the terminal control cycle and supports identification of crisis-related risks across hierarchical levels. Experimental validation indicates reduced probability of operator errors and improved decision-making speed. The proposed model extends traditional coordination and DSS approaches by ensuring compatibility with modern digital infrastructures. Its architecture supports integration into smart factories, cyber-physical systems, energy and transport networks, and AI-driven management platforms. The results contribute to digital transformation by improving resilience, enhancing real-time coordination, and reducing the impact of human-related uncertainties in hierarchical control processes.

Keywords
expert system, strategy, coordination, synthesis, hierarchy

1. Introduction

In a technogenic hierarchy (including production, transport, organizational and administrative management units, printing, and media), the formation of the security system structure is based on systemology and goal-oriented decision-making methods aimed at solving crisis-related problems. The analysis of emergency and risk situations under the influence of active threats and attacks has demonstrated the importance of developing models of coordination strategies for decision-making in hierarchical technogenic structures. Such models enhance the resilience of these systems to external negative impacts, threats, and attacks, and improve management efficiency through the implementation of inter-level integration and stratification of the control process.

At the current stage of the development of technological systems, it is characteristic that control decisions are made at different levels of the hierarchy, ranging from automatic control systems (ACS TP) to operational control by personnel and coordination management by higher levels. At the same time, higher levels do not always possess the appropriate level of professional and specialized training and often lack understanding of the content of technological situations during changes in the modes of supply of energy and material resources, as well as the influence of both external and internal disturbing

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factors. Particularly dangerous is the factor of misunderstanding that, when technological processes are brought to boundary modes with outdated equipment having reduced operational resources, emergency situations may arise. The solution to this situation is the development of a decision support system (DSS), the structure of which includes system experts, systems of intelligent data processing, and information-measuring systems for automatic database population.

The proposed approach forms a new type of coordination model for hierarchical technogenic systems, which significantly expands modern research by integrating goal coordination, cognitive characteristics of the operator, and strategy generation algorithms into a single formalized structure. Unlike existing models of coordination management, traditional DSS, and cognitive schemes, the proposed model simultaneously considers: the state of the control object, the target space of all levels of the hierarchy, the level of information and intellectual readiness of the operator, as well as risk factors that arise in crises. The novelty of the approach lies in the introduction of formalized intervals of cognitive operations and procedures for goal compatibility, which allows building strategies that are adaptive to uncertainty, structural disturbances, and threats to cyber-physical infrastructure. The practical advantages of the model are manifested in increasing the accuracy of the choice of control actions, reducing decision-making time, reducing the risk of incorrect or incompatible strategies, as well as significantly reducing the influence of the human factor due to clearly structured criteria for operator assessment and automated formation of strategies in crises.

2. Overview of research studies

The growing scientific interest in the issues of coordination control in hierarchical technogenic systems is driven by the increasing complexity of modern cyber-physical and socio-technical systems. Studies by Ukrainian scholars [1, 2] emphasize that the effectiveness of managing multilevel structures largely depends on the ability to coordinate decisions across different hierarchy levels, ensuring consistency between local actions and global strategic goals. In [3], a two-level hierarchical decision-making model is proposed, structuring the process into sequential stages: the first level narrows alternatives according to strategic considerations, while the second level re-evaluates selected options based on feasibility. Such a multi-level design refines the decision-making pathway and improves interpretability compared to single-level approaches.

Modern approaches to modeling coordination control combine methods of systems analysis, decision theory, game theory, and intelligent modeling, as demonstrated in [4, 5, 6]. In particular, [7, 8] explore hierarchical decision-making models with distributed agents interacting within coordinated management strategies for critical infrastructure systems, and propose game-theoretic approaches to operational security research through scenario modeling. The authors show that building an effective coordination strategy requires formalizing relationships between control levels, where the upper level defines objectives, and the lower levels optimize local states under given constraints.

Study [9] focuses on cyber-physical system models that enable the integration of distributed energy resources (DERs) into networks and the creation of adaptive communication layers for efficient control and management of DERs. However, this approach introduces new vulnerabilities to cyber-physical attacks. Coordination of actions at various hierarchy levels is analyzed using leader–follower [10] and multi-agent coordination models [11]. Similar principles are applied in [12, 13] to build dynamic hierarchical models that account for stochastic influences.

An important role in contemporary research is played by the cognitive approach to modeling management processes, where decision-making is viewed as an interaction among subjects with different levels of competence. In the monograph [14], a cognitive-oriented coordination model is developed, in which managerial decisions are formed through the alignment of participants' mental models and decision support during strategic crisis management (e.g., during the COVID-19 pandemic). Study [15] decomposes decision-making into delegated authority frameworks, emphasizing that autonomous actions still require confidence and knowledge for effective decisions, and explores the role of intuition as a factor ensuring autonomy in emergency response systems. Publications [16, 17] demonstrate that the cognitive stability of decision-makers is a key determinant of effective crisis response in technogenic systems.

In [18], the authors present models of operational control for technological production processes within complex hierarchical systems and economic networks under conditions of emergencies and natural disasters. Meanwhile, research [19] focuses on a decision support system designed for risk identification and assessment in complex hierarchical management environments. Drawing on the theoretical foundations and practical insights proposed in these works, it becomes possible to enable efficient real-time planning and synchronization of management processes across all system components — encompassing both structured management teams and unorganized human groups operating in high-risk or crisis situations.

Considerable attention is also given to optimization-based approaches in modeling coordination strategies. Studies [20, 21] propose the use of evolutionary algorithms, stochastic optimization, and fuzzy logic for adaptive alignment of goals across different management levels. Such methods allow the formation of consistent solutions even under incomplete information or dynamic system parameters.

Within the framework of systems analysis of complex technogenic objects, works [22, 23] discuss the concept of multilevel management, which integrates strategic, tactical, and operational decision-making levels. The authors note that improving the resilience of hierarchical systems requires developing feedback procedures that ensure adaptation of strategies to the current state of the controlled object.

Modern manufacturing is increasingly characterized by complex processes and the need for high-precision real-time data for effective decision-making. Studies [24, 25] investigate Manufacturing Execution Systems (MES) as a critical link between enterprise-level planning and shop-floor operations, providing functionalities such as production scheduling, batch tracking, and quality management. The Industrial Internet of Things (IIoT) addresses challenges in obtaining accurate data on the state space of the controlled object and its goal-oriented state space. This is achieved through automated data generation based on sensors and intelligent coordination management using machine learning and neural network models. Such systems can predict the outcomes of managerial decisions and adjust strategies in real time.

Article [26] presents a comprehensive literature review of recent developments in anomaly detection methods for identifying security threats in cyber-physical systems. In industrial control networks (ICNs), issues related to safety and reliability are of paramount importance, particularly due to the increased connectivity to the Internet, which raises the vulnerability of critical infrastructure. This has made incidents targeting pipelines and power grids more frequent and severe, especially in the context of the growing number of cyberattacks and terrorist threats.

In summary, despite a significant number of studies devoted to coordination in hierarchical systems, issues of formalizing coordination decision-making strategies in the context of technogenic systems with high levels of uncertainty remain insufficiently explored. Further development of a mathematical framework is needed to align the state space of the control object with the system's goal space, ensuring flexible strategic management across all hierarchy levels.

3. Coordination of local strategies as a means of ensuring guaranteed functioning of technological structures

The coordination of subsystems of the n-th level of the hierarchy defines such a control action on the subsystems that forces them to function coherently in accordance with their local goals in such a way that the entire system achieves the overall objective. Since the lower-level systems have their own goals, which may not coincide with the goals of the upper hierarchical levels, conflicts may arise over resources, control strategies, and goal orientation, leading to the impossibility of achieving the global goal.

The actions of the strategic coordinator are aimed at

- decomposition of the global goal into local ones; coordination of strategies for achieving goals and terms of implementation;

- coordination of resource distribution for all hierarchical levels;
- distribution of decision-making authority for each level of the hierarchy and the determination of priorities;
- formation of a set of ranked quality criteria of control associated with risk optimization, the level of resource consumption, and guarantees of goal achievement.

The concept of coordination is associated with the procedures of goal-oriented decision-making and the evaluation of success in achieving the goal based on the decomposition of the control problem:

$$\exists \mathrm{StratDcom}(CZ), \quad \exists \mathrm{Strat} RZ_U^{C_i}(X); \ \forall t \in T_m \subset T_D, \tag{1}$$

where $\exists \Pi_R : \forall (x, D_{RZ}), P(x, D_{RZ}) \overset{T_m}{=} x_i$ is the solution of the i-th problem with respect to the goal G_i at the terminal time, at which $X_i(t) \in W_c$. Then $\exists \gamma_k \subset \{U_k\} \exists Strat_k(U_k|C_i|T_D)$, which order the sequence of problems $\{D_{RZ}^0, D_{RZ}^1, \ldots, D_{RZ}^m\}$, under $\gamma_k(t|T_m)$, $T_m - \min T_u$, $t_{ui} \subset T_U$, where: Π_R – rule or algorithm for solving the problem; t – current time; $\mathrm{Strat} RZ_U^{C_i}(X)$ – problem-solving strategy; T_m – terminal time; $\mathrm{StratDcom}(CZ)$ – decomposition strategy of the problem; T_D – allowable time; γ_k – coordinating signal from the set of control actions; T_U – control action time; $\{U_k\}$, D_{RZ}^i – solvable problem; t_{ui} – control implementation time; W_c – target region; $Strat_k(U_k|C_i|T_D)$ – coordination strategy of control actions U_k to achieve goal C_i.

Accordingly, it is possible to distinguish classes of signals according to their functional purpose: $KL_j(S_i|_{i=1}^n)$ – classes of signals from each level that determine the state of objects and strategies of the lower level; $KL_j(\gamma_k|U_k)$ – classes of control signals directed from the upper level to the lower one, which are formed based on the results of solving current control problems D_{RZ}^i.

The efficiency of control in a hierarchical system is based on inter-level integration and stratification.

Definition 1. Integration — hierarchical ordering during the unification of systems with the purpose of organizing operational functioning and increasing efficiency in achieving the goal. Accordingly, the coordination of interacting subsystems improves the way of achieving the objective at all hierarchical levels, in accordance with the goal achievement strategy based on the choice of the procedure for searching the scheme of solving the control problem.

3.1. Procedures for searching schemes for solving the control problem

The problem of finding solutions in the target space conjugated with the state space is based on the search for mappings $(X \times T_m) \to (X \times T_D)$, for which we have.

$$\begin{cases} g : x \to V, \ \ Rangx = n+1, \ \ \exists X^f, \ \ \exists \hat{x} \in X^f; \\ \forall x \in X^f : g(\hat{x}) \leq g(x), \ \ \text{where } G_p : x \to y, \ \ G_v : Y \to V_c. \end{cases} \tag{2}$$

where $X_{U_i}^{T_{mi}}$ – the set of all solutions for the states of the system (control object) under control U_i and time T_{mi}; X^f – the set of admissible solutions, $X^f \subset X_U^{T_m}$, $X^f \notin W_A$; G – the objective function $(G = G_p \bigotimes G_V)$; W_A – the emergency (failure) region; V_c – the cost of achieving the goal at time t_{C_i}; G_p – the output function as a model of the control process; G_V – the control quality functional; Ω – the set of uncertainties in the state of the control object; F_τ – the tolerance function, for which the following relations hold:

$$\forall (x, \omega) \in [X \times \Omega] \, \exists F_\tau. \tag{3}$$

$$G(x, \omega) \leq F_\tau(\Omega), \tau : \Omega \to V, \tag{4}$$

thus, we obtain the condition of a satisfactory solution to the control problem [1].

Let us construct the state space and the target space accordingly (Figure 1a, b), on which we define the cone of control trajectories.

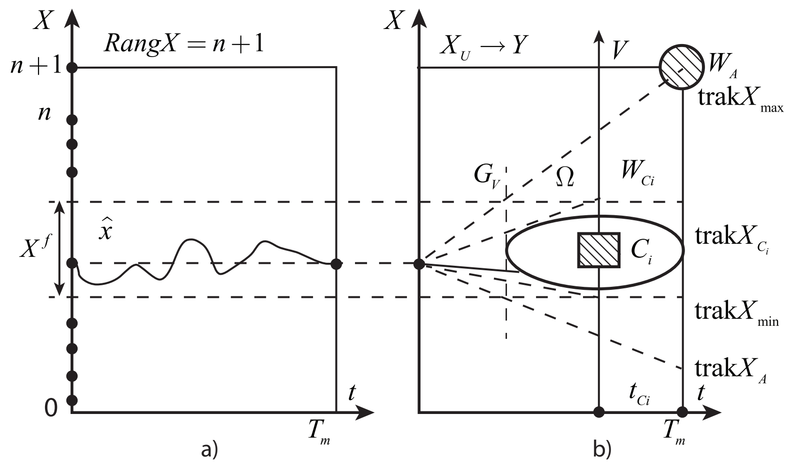

Figure 1: State space of the control object (a) and target space (b).

The objective function can be defined considering the set of influencing factors in the form of mappings on the target space:

$$\{G_p : X \times \Omega \to Y,\ G_V : X \times \Omega \times \to V_C\} \mapsto \langle G(x, \omega) = G(x, \omega, G_p(x, \omega))\rangle\,, \tag{5}$$

where G – is the objective function on Ω – the domain of uncertainty (both structural and parametric), which depends on the control strategy, the problem situation, and the decision-making procedures.

3.2. Decision support system

Definition 2. $[S \subset X \subset Y]$ is called a Decision Support System (DSS) if a family of problems $\left\{ZD_x^i, x \in X\right\}_{i=1}^m$ from the set of solutions Z and the mapping $\{T : z_i \to Y, \forall x \in X, \forall y \in Y\}$, are defined, for which the existence condition of the solution holds: $\exists z_i \in Z : ZD_x : T(z_i) = y, y \in C(C_i)$ in the goal space of the system $(C_i) \subset Y \times T_{m_i}$ for the terminal time T_{m_i} – based on the scheme of selecting strategies $StratR(ZD_x + T_D)$, hat ensure its achievement within the permissible time t (Figure 2).

Problem I. Synthesis of the Coordination System. If a global problem is given, along with the procedure for its decomposition into different levels, it is necessary to find such a problem for which a common coordinating strategy exists, based on which control signals are generated for all levels:

$$\exists\,(PZ|T_m \in T_D)\,, \exists\Pi_R : D\left(PZ \to LZ_i|_{i=1}^m\right), \Pi_R \to \mathrm{Strat}\,(U_i|C_i)\,. \tag{6}$$

Problem II. Selection of the Method, Procedure, or Coordination Algorithm. If the structure of the system is given and conjugated with respect to the target problem, it is necessary to find an effective method or algorithm for obtaining (forming) a coordinating signal that would ensure the coherent behavior of the system to achieve the goal:

$$(G(PZ_{C_i}) \leftrightarrow \mathrm{Strukt}\,(ISU)) \mapsto [\exists\mathrm{Strat}\,(U\,|C_i|\,T_m) : Z_i \in W_c]\,. \tag{7}$$

Problem III. Modification of Strategies. If the hierarchical system is not coordinated with respect to the problem $PZ(X \times T_m)$, it is necessary to find such a modification of the problem for which a coordinating strategy exists:

$$\{\exists\mathrm{Strat}\,(U\,|C_i|\,T_m) : Z_i \notin W_c\} \Rightarrow \Pi_R^K : \left(\mathrm{Strat}U_1 \xrightarrow{K} \mathrm{Strat}U_K\right). \tag{8}$$

Problem IV. Decomposition of the Global Problem. If only the global problem is formulated, it is necessary to establish procedures for dividing it into classes of upper- and lower-level problems, so that the strategy for their solution is coordinated with respect to the upper-level problem.

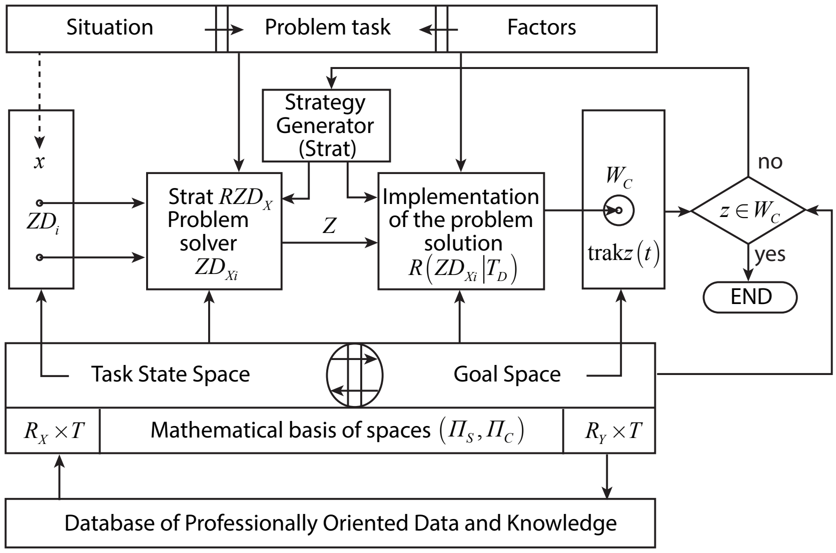

Figure 2: Scheme of strategy generation for solving coordination control problems.

If the problem is formulated at the upper hierarchical level, the challenge arises of finding a scheme for its solution, which involves two aspects:

1. Searching for or generating a strategy for solving the coordination control problem;
2. Synthesizing a new system structure according to the goals and coordination strategy, or modernizing and organizing the existing system according to the problem-solving scheme and procedure.

In accordance with these conditions, the scheme for selecting coordination strategies is constructed (Figure 3):

- based on the problem situation in the i-th cycle, the problem is formulated;
- according to the coordination principle, target control problems are generated within the hierarchy;
- the compatibility condition of goals is checked, and the problem-solving strategies are selected from the knowledge base, and the coordination control scheme is built according to the hierarchical levels and type of structural organization.

The proposed model of coordination management is organically integrated into the modern IT environment, focused on digital transformation and intelligent decision-making support technologies. The architecture of the model involves the use of digital sensors and information and measuring systems for automated formation of the state space, machine learning modules for predicting crisis scenarios, as well as intelligent risk analysis algorithms for coordinating management strategies between hierarchy levels. The results of real-time data processing allow the DSS to offer optimal management actions and reduce dependence on subjective operator decisions. Such integration ensures the compliance of the model with modern trends in AI-driven management, increases the level of automation, and makes it compatible with digital platforms for managing technogenic and cyber-physical systems.

4. Research results

As a result of the conducted research, based on the implementation of a game-based coordination strategy model for a hierarchical control system, the following factors influencing the emergence of crisis-related risks were identified:

- factors related to assessing the state of controlled objects at the terminal stage of the technological process because of detected errors;

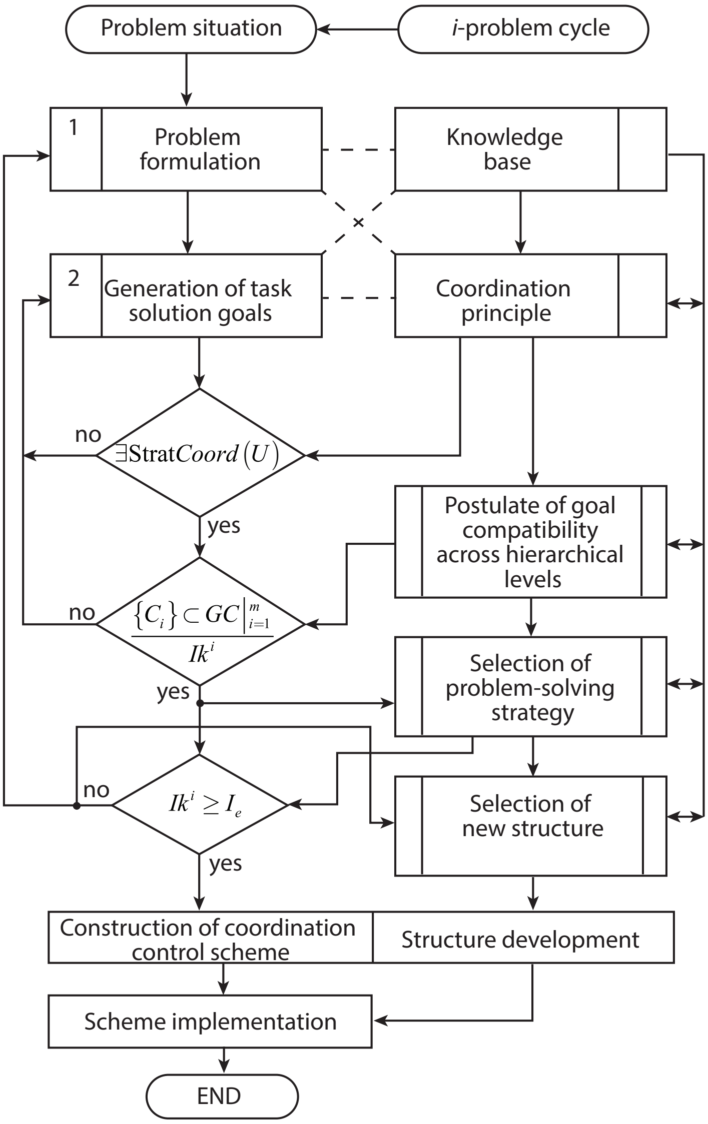

Figure 3: Functional scheme of the model for selecting a coordination strategy for a hierarchical control system.

- factors associated with deviations from operational modes within the technological production process and with non-compliance with key parameters defined by regulatory documentation;
- factors resulting from inconsistencies between the structure and functions of the control system and the cognitive as well as physiological-psychological characteristics of the decision-maker;
- factors arising from errors in operation manuals for technogenic equipment or untimely updates of these manuals in accordance with changes in the operating modes of ACS TP, ACS, and IASU units;
- factors related to insufficient professional knowledge of the operator-manager and the lack of systemic thinking.

The study involved systemic and logic-cognitive procedures used by operational personnel to assess problematic situations that must be addressed to mitigate the risk of accidents within cognitively intensive managerial activity. The research results are presented in Table 1.

The cognitive characteristics of the decision-making operator (DMO) in crisis situations were determined based on expert assessments derived from testing conducted at technogenic energy enterprises in the Lviv and Ivano-Frankivsk regions of Ukraine. These characteristics reflect the operator's ability to resolve complex crisis situations under conditions of threats and attacks. For the analysis of the

Table 1
Classes of Cognitive Operations and Their Value Intervals

№	Class of Operations	Code	Interval
1	Identification of risk factors	F_r	0.5–1.0
2	Formulation of a problem situation based on data assessment	FP_s	0.75–1.0
3	Development of a decomposition process for the problem situation and execution of tasks	FP_s	0.8–1.0
4	Identification of problem-related tasks	VP_z	0.9–1.0
5	Generation of goal-oriented hypotheses	GC_h	0.9–1.0
6	Selection of task-solving strategies	V_{strz}	0.9–1.0
7	Management of the problem-solving process	URP_s	0.8–1.0
8	Analysis of results and coordination of goal-achievement processes	AK_c	0.8–1.0
9	Selection of arithmetic and logical operations for implementing problem tasks	VAL_z	0.75–1.0
10	Formation of a structural organization of operations for implementing an action program aimed at solving the crisis-related task	FPD	0.65–1.0
11	Identification of crisis situations during the task-solving process	VKS_z	0.5–1.0
12	Selection of methods for identifying the structure and dynamics of the object	VMI_s	0.75–1.0
13	Selection of methods and tools for data acquisition and their assessment	VMZ_d	0.5–1.0
14	Ability to process heterogeneous data	F_{rd}	0.5–1.0
15	Intellectual interpretation of situational patterns within the system	III_s	0.8–1.0

DMO's cognitive reactions, the following types of crisis situations were considered:

- resource failures (material or energy-related);
- operational mode deviations of objects, loss of reliability of units, or errors made during task correction;
- personnel disorientation caused by incorrect operator instructions.

In accordance with the above requirements, knowledge and skill tables were developed to characterize the DMO's performance in crisis situations (Table 2). Based on the tests assessing the level of information-technology competence in hierarchical technogenic systems, the components and their permissible values required for the operator—as a cognitive agent—to implement the system's crisis management process were determined.

Table 2 presents the knowledge-based framework of requirements necessary to ensure crisis-management capabilities under the influence of threats, attacks, and internal conflicts within operational and administrative control systems. Based on the research results obtained in this study, it becomes possible to conduct the preparation and selection of individuals who will make decisions in the management of hierarchical technogenic systems.

To verify the reliability of the results, an expert assessment was conducted with the participation of 18 specialists (operators, ASC engineers, and technical safety specialists). The cognitive characteristics of the operators were assessed using the modified Delphi method using a 10-point scale normalized to the interval [0; 1]. The values of the intervals in Tables 1–2 were calculated by the method of normalization and averaging of expert assessments, with further stability verification through confidence intervals. The model was validated based on a simulated crisis scenario (sudden deviation of the technological

Table 2
List of required knowledge and skills for a decision-maker

№	Information technologies in management	Components	Data
1	Knowledge of the dynamics of the object	$Z(PS)$	>0.8
2	Knowledge of the type and models of the target space	$Z(M)$	>0.9
3	Knowledge of methods for goal generation	$Z(GC_i)$	>0.9
4	Knowledge of methods for constructing logical chains	$LI(UI)$	>0.8
5	Understanding the informational content of the situation	IR_{icon}	>0.7
6	Ability to form logical chains for constructing control actions	$IRLogU$	>0.9
7	Knowledge of methods and tools for data collection and processing from the controlled object	$IR(IVS)$	>0.75
8	Understanding the essence of implementing goal-oriented actions	$IR(C_j)$	>0.9
9	Understanding the essence and purpose of goal-oriented coordination of system control	$IR(C)KoordU$	>0.8
10	Understanding the nature of cyberattacks on the system, and the assessment and classification of risks	$IO\alpha_{risk}$	>0.75
11	Ability to predict event scenarios based on preliminary processing of data flows and situational patterns	$PRGSupP_i$	>0.75
12	Ability to classify the operating mode of the object based on current data	$KL(x_i)$	>0.6
13	Ability to assess risk levels based on informational and intellectual data processing	$LR\alpha_{risk}$	>0.75

process parameters and operator error). A comparison of the two modes – without DSS and with the use of a coordination model – showed a reduction in the risk of emergency decisions by 31% and a reduction in response time by 17–22%, which confirms the effectiveness of the proposed approach.

5. Discussion

According to the definition of interlevel integration of the control system for hierarchical technogenic structures presented in this study, an important stage in constructing a decision-making model is the coordination of interacting systems to solve strategic tasks–achieving goals at all levels of the hierarchy. To accomplish this, it is necessary to implement new models in the hierarchical control system that are based on procedures for searching schemes for solving control problems under critical situations. For the training of personnel – decision makers (DMs) – it is essential to develop game-based simulation models of critical situations within the control system to develop their cognitive skills for responding under crisis conditions and to prevent the occurrence of emergency situations at the terminal control cycle. Under real operating conditions of a hierarchical technogenic structure, the model of coordination of decision-making strategies must determine the state space of the control object at the terminal cycle and align it with the target space at all levels of the control hierarchy.

The decision support system for crisis situations is built based on situation analysis and selection of control strategies aimed at goal orientation and minimization of the risk of emergency situations. For the correct selection of control strategies in the model of coordination strategies for decision-making, it is necessary to have a mathematical basis for the state spaces of control objects and the target spaces for strategic management of the technogenic system, which is formed based on the professional data and knowledge base. Therefore, an important stage in the implementation of such models is the creation of professional game-based models and the training of decision makers.

Compared to existing approaches – models based on game theory, multi-agent systems, and fuzzy-oriented DSS – the proposed coordination model demonstrates the advantage of combining target compatibility, operator cognitive characteristics, and hierarchical coordination of strategies, which is rarely implemented in a comprehensive form. At the same time, the model has several limitations, in particular, dependence on the quality of expert assessments, sensitivity to incomplete or noisy data, and the need for high-speed mechanisms for real-time information processing. Further development of the research involves the creation of a simulation environment for training operators in behavior in crises, automation of strategy generation using intelligent algorithms, and research into the possibility of using reinforcement learning for adaptive optimization of coordination in complex man-made systems. Such an extension will allow for increasing the autonomy of the DSS, reducing dependence on the human factor, and improving the system's resistance to dynamic threats.

The proposed coordination model has significant potential for use in digital transformation and can be integrated into modern cyber-physical systems, in particular, smart-factory platforms, energy complexes, transport systems, and aviation technological environments. Due to the formalization of the state space, risk assessment mechanisms, and algorithms for coordinating management actions, the model can work with data flows in real time, which makes it compatible with IIoT infrastructure, digital twins, and AI-oriented control systems. Such integration ensures adaptability to dynamic technological changes, increases control autonomy, and allows the model to be effectively applied in industrial automation, energy networks, logistics operations, and critical aviation safety systems, where a high level of coordination and efficiency is a key factor in resilience.

6. Conclusions

The concept of constructing a model of coordination control in a hierarchical system based on the procedure of aligning strategic goals with the local goals of each stratum has been considered. It has been shown that the procedure for synthesizing coordination strategies will be effective only if the upper level of the management hierarchy is guided by managers with a high level of professionalism and intellectual resilience, since these personal qualities are developed over many years of preparation, whereas crisis situations often have an explosive nature. Consequently, managerial commands may drive the system into an emergency state due to the inability of the upper level to make effective decisions.

The proposed procedures for searching schemes of control problem solutions are based on the coordination of the control object's state space with the target space, ensuring goal-oriented coordination at all levels of the hierarchical structure of technogenic systems. The evaluation of crisis situations is based on determining the control strategy, identifying the problem situation, and constructing the decision-making procedure.

The generation of control strategies is grounded in the coordination of management processes across all hierarchical levels with respect to the primary control objective (goal orientation) and the problem-solving strategy using the model of coordination strategies for decision-making. Such a mechanism enables DMs to select management and coordination strategies for all control decisions within hierarchical management systems.

The selection of individuals who make decisions in hierarchical technogenic systems is carried out according to the criteria and requirements for the cognitive characteristics of decision-makers to ensure effective crisis management under the influence of threats and attacks. The factors influencing the emergence of crisis-situation risks, examined in this study, as well as the assessment components and their allowable values developed on the basis of testing, make it possible to perform such selection and to control the level of knowledge of information technologies required for implementing the system-management process in crisis situations by the operator as a cognitive agent.

Further research by the authors will be aimed at expanding the presented model by developing a full-fledged practical case for various types of crises in man-made systems, including emergency deviations of technological processes, equipment failures, and cyber threat scenarios. It is planned to create a detailed scenario experiment with a comparison of manual decision-making and the work of the DSS coordinator, which will allow assessing the effectiveness of the model in real conditions and deepening its applied validation.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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