17TH INTERNATIONAL CONFERENCE ON MANAGEMENT OF LARGE-SCALE SYSTEM DEVELOPMENT (MLSD'2024)

Since 2007, the Trapeznikov Institute of Control Sciences, the Russian Academy of Sciences (ICS RAS), has been organizing the International Conference on Management of Large-Scale System Development (MLSD). The conference brings together scientists and experts from academia, research organizations, and higher education institutions.

This annual September event provides a unique opportunity to discuss recent achievements in basic and applications-relevant research in a wide range of areas.

Section 1. Management problems of large-scale system development, including multinational corporations, state holdings, and state corporations

Section 2. Methods and tools for managing investment projects and programs.

Section 3. Management of development of a digital economy. Design offices, both situational and expected analytical centers, institutes of development of large-scale systems.

Section 4. Simulation and optimization in the problems of development management of large-scale systems.

Section 5. Nonlinear processes and computing methods in the problems of management of large-scale systems.

Section 6. Management of development of banking and financial systems.

Section 7. Management of fuel, power, infrastructure, and other systems.

Section 8. Management of transport systems.

Section 9. Managing the development of aerospace and other large-scale organizational-technical complexes.

Section 10. Managing the development of regional, urban, and municipal systems.

Section 11. Management of objects of nuclear power and other objects of increased danger.

Section 12. Information support and software management systems for large-scale production.

Section 13. Methodology, methods, software, and algorithmic support of intellectual processing of large volumes of information.

Section 14. Monitoring in the management of large-scale systems.

Section 15. Management of large-scale systems advancement in healthcare, medico-biological systems, and technologies.

Section 16. Managing the development of social systems.

As demonstrated by these sections, MLSD is an excellent platform for discussing advanced trends in mathematical modeling focused on the development of digital analytics for Russia's strategic management. Potential participants are invited to submit original and previously unpublished R&D results. All submissions are peer-reviewed by several technical groups. Accepted papers are published in two conference proceedings, all in Russian and selected and extended ones in English, indexed by the National Electronic Library (eLIBRARY.RU) and IEEE *Xplore* (Scopus), respectively.

The 17th International Conference on Management of Large-Scale System Development (MLSD'2024) was held on September 24–26, 2024, with the technical support of the IEEE Russia Section. The event was attended by 393 researchers from over 48 research institutes, universities, and governmental and commercial organizations, including two academicians and three corresponding members of the RAS, 88 doctors of sciences, and 130 candidates of sciences. To date, the Proceedings of MLSD'2024 have been published, with 195 Russian-language papers in eLIBRARY.RU and 169 English-language papers in IEEE *Xplore*.[1]

At the opening ceremony, *D.A. Novikov*, director of ICS RAS and Academician of the RAS, known for his pioneering research into the mathematical modeling of interdisciplinary systems, addressed the conference participants with a welcoming speech. He highly appreciated the annual MLSD conferences and strongly recommended developing the theory and methods of mathematical modeling in the management of large-scale systems.

According to the analysis results, the peculiarity of this year's conference is that the plenary and sectional sessions are focused on Russia's urgent strategic management tasks outlined in federal-level documents.

[1] https://ieeexplore.ieee.org/xpl/conhome/10739406/proceeding

The plenary paper "Problems of Management of Large-Scale System Development in Modern Conditions" by Dr. Sci. (Eng.) *A.D. Tsvirkun* (ICS RAS) was devoted to key problems of bringing Russia to the economic growth trajectory [1]. He considered the Strategy for Scientific and Technological Development of the Russian Federation[2] as a key factor contributing to the country's readiness to respond to global challenges effectively. The high pace of creating knowledge-intensive products on a national technological basis determines the competitiveness and effectiveness of national security strategies. As noted in the paper, large-scale systems are the most adequate field of modern strategic planning for the national economy's development. As an example, the author described a set of models for the development of a large-scale production and transportation system and presented a methodology for elaborating investment projects for groups of enterprises and companies with a complex internal structure.

In another plenary paper, Dr. Sci. (Eng.) *O.I. Dranko* (ICS RAS) considered the issues of controlling the achievement of national strategic management targets [2]. His main idea is that indicative planning represents the most important tool for shaping Russia's future national economy in the long term. The paper formalized an effective strategic planning and control mechanism based on modern technologies of monitoring and analytical economic and mathematical modeling. Structurally, the indicative planning system proposed by the author is a multilevel complex of "Country–Industries–Enterprises–Products" models intended to find priority points of accelerated growth in individual industries and decompose them at the level of particular organizations. The model's operation was demonstrated on the example of analyzing and forecasting the country's rank by Gross Domestic Product at Purchasing Power Parity (GDP at PPP). The rank was calculated by target indicators for industries and organizations. The problem of linking GDP with output (orders) was also formulated. To implement the target scenario, the necessary growth rates of GDP and gross value added (GVA) of individual industries were estimated based on the data of the World Bank, the Federal State Statistics Service (Rosstat) and the Federal Tax Service (FTS) of the Russian Federation. The model allows studying different scenarios of changing target settings. Resource indicators serve to consider resource constraints, assess the real level of target achievement under different resource scenarios, and evaluate the efficiency of resource utilization under different target achievement strategies. Data from Rosstat and FTS were used as input data; at the lower level, information from BI and ERP systems of enterprises.

Academician of the RAS *S.P. Filippov* and Cand. Sci. (Econ.) *F.V. Veselov* (Energy Research Institute (ERI) RAS) presented their plenary paper "Improving the Management System of Scientific and Technological Development of Russia in the New Geopolitical and Economic conditions." They discussed the transition to a carbon-neutral economy based on domestic energy developments and technologies. As emphasized in the paper, climate policy is crucial to determine the future evolution of the world economy and energy sector. Under these conditions, the development of a high-performance low-carbon economy, energy saving (in production, transformation, transportation, and consumption), carbon dioxide capture, production of renewable energy sources, etc. is of particular importance in strategic planning.

Several sectional papers of other ERI RAS employees were devoted to solving this problem posed by the Institute's Director *S.P. Filippov*. In the paper "Rising Energy Domestic Prices and Russia's Forecast GDP Rates," Cand. Sci. (Econ.) *V.A. Malakhov* and *N.V. Leokumovich* concluded on the determinative impact of the price of electricity and heat on GDP dynamics [3]. In this regard, the authors stressed the need for a price compromise between producers and consumers of energy carriers within the economic growth rates planned by the Government of the Russian Federation.

The paper "An Approach to Soft Linking Capacity Expansion and Dispatch Models to Assess the Flexibility of the Future Energy System Using the Example of the UPS of Russia" (Cand. Sci. (Econ.) *R.O. Alikin*, *I.V. Erokhina*, and *A.A. Khorshev*) analyzed the problems arising on the way to achieving carbon neutrality by 2060. The authors paid attention to the fact that the growing electricity production from renewable sources, the increasing role of solar energy, and the decreasing share of coal in the Russian energy sector objectively impose stronger requirements for the flexibility of operation and adaptation to new energy balance structures. In addition, they proposed a future energy system model open to changes in the structure of sources and the expansion of their capacities.

The paper "Increasing the Continuity of Centralized Heating Supply System" by Cand. Sci. (Eng.) *E.E. Boyko* and Dr. Sci. (Eng.) *P.V. Ilyushin* concerned the urgent problem of reducing the risks of accidents with prolonged shutdowns of heat consumers

[2] Decree of the President of the Russian Federation dated February 28, 2024, no. 145 "On the Strategy of Scientific and Technological Development of the Russian Federation." URL: https://www.garant.ru/products/ipo/prime/doc/408518353/ (Accessed September 10, 2024.)

in densely populated urban and industrial areas of regions, including countries with sharply continental climate. They proposed a centralized heating supply system model supplemented with an active thermal automatic control system.

The energy system model was presented in the paper "The Problem of Global Energy Flow Management" by Cand. Sci. (Phil.) *K.M. Shurunov* (the Moscow Institute of Physics and Technology) and Dr. Sci. (Eng.) *O.I. Dranko* (ICS RAS) [6]. The model of global energy flows considered therein covers the entire supply chain of energy and goods realized in the international market. The authors studied the dynamics of structural changes in global energy flows in the 21st century; identified the main sectors of the economy contributing to the carbon footprint; and determined the historical redistribution of global energy flows. Note that energy flows were analyzed using OECD data (TiVA).

Two plenary papers were devoted to the implementation issues of some directions of the Energy Strategy of the Russian Federation.[3] In particular, the paper "Energy Metrics of Large-Scale Dynamic Networks" by Dr. Sci. (Eng.), Prof. *I.B. Yadykin* (ICS RAS) considered the topical problem of a sustainable energy sector [7]. Energy metrics are quantifiable indicators intended to assess the level of efficiency and rationality of energy resources utilization. An example is the energy efficiency index, which evaluates the use of all major energy resources (electricity, water, wastewater, gas, heat and hot water supply, motor fuel, and cold) and the key operating mode parameters of an enterprise that determine energy costs. The author introduced original structural and spectral methods and models of large-scale dynamic networks based on graphs given by the state equations of energy metrics of these models in various canonical forms.

According to the Energy Strategy of the Russian Federation, a main challenge in subsoil use is to change the structure of explored reserves of fuel and energy resources toward hard-to-recover and complex-component ones. The plenary paper "Thermal Wave Processes of Control the Development of Oil Fields with Abnormally High-Viscosity Reserves" (Cand. Sci. (Eng.) *A.V. Akhmetzyanov* and Dr. Sci. (Eng.) *A.V. Samokhin* (ICS RAS)) was aimed at solving this problem [8]. The authors proposed a mathematical model of the extraction processes of hard-to-recover oil reserves using heating. The model represents high-frequency wave oscillations of heating intensity that increase the efficiency of extraction.

A key target of the Transport Strategy of the Russian Federation[4] is digital transformation to improve the spatial connectivity and transport accessibility of territories, increase population mobility, raise the volume and speed of cargo transit, and develop multimodal logistics technologies. Dr. Sci. (Eng.), Prof. *V.V. Tsyganov* paid special attention to the research and development of theoretical and methodological foundations necessary to achieve these targets. In his plenary paper "Strategic Adaptive Transport Management," he described in detail and illustrated on a particular example the modular approach and digital learning principles underlying adaptive transportation management. Unlike conventional traffic control modes with fixed schedules, adaptive control involves real-time data and advanced algorithms to tune the timing of traffic signals. This enables proactive control of possible congestion and accidents, which significantly improves the efficiency and safety of transport.

Note the following three sectional papers as examples dealing with advanced mathematical models of the digital transportation system.

In his paper "Mathematical Algorithms for Containers Area," Cand. Sci. (Phys.–Math.) *S.A. Savushkin* formally described the container section and railroad front of a terminal-logistics center [10]. The problems of rearrangement of containers and loading of trains with the least number of crane movements were stated. The corresponding concepts were formally defined in terms of set theory, and movement planning algorithms were presented. In addition, possible deadlock situations in the operation of some algorithms were revealed.

D.V. Khablov's paper "Vehicle Cruise Control with Lane Keeping Based on Measuring the Speed Vector and Trajectory Curvature Using Microwave Sensors" considered a model of automatic vehicle control for collision avoidance and lane keeping [11].

The paper "Cyber-Physical System Development to Improve Energy Supply on Transport by Causal Approach" (Dr. Sci. (Eng.) *A.A. Bezrodniy*, Dr. Sci. (Eng.), Corresponding Member of the RAS *A.F. Rezchikov*, and Cand. Sci. (Eng.) *I.A. Stepanovskaya*) was devoted to the development of a breakthrough technology for designing large-scale cyber-physical systems in the neural network format with extending their standard tools based on the ontological model of caus-

[3] Order of the Government of the Russian Federation dated June 9, 2020, no. 1523-r (as amended on October 21, 2024) "On Approving the Energy Strategy of the Russian Federation for the Period up to 2035." URL: https://docs.cntd.ru/document/565068231?ysclid= m52cxpmh7i781727999 (Accessed July 10, 2024).

[4] Order of the Government of the Russian Federation dated November 27, 2021, no. 3363-r "On Approving the Transport Strategy of the Russian Federation until 2030 with a Forecast for the Period up to 2035." URL: https://mintrans.gov.ru/documents/2/11577 (Accessed July 10, 2024.)

al relations [12]. The authors considered the models of control structures and algorithms forming the mathematical support of artificial intelligence on the example of the joint development of transport, energy supply, and communication systems.

In the paper "Optimization of Heterogeneous Cargo Transportation Plan in Unmanned Air Transportation System by the Criterion of Minimum Time," Cand. Sci. (Eng.) *A.G. Podvesovskii* (Bryansk State Technical University), Dr. Sci. (Eng.), Prof. *R.V. Meshcheryakov* and Dr. Sci. (Eng.) *A.A. Zakharova* (ICS RAS) proposed an optimization model and a methodology for finding an optimal plan with the minimum cargo transportation time under routing network capacity constraints [13].

Note that the implementation of the Transport Strategy is closely related to the strategic planning of the development of federal subjects[5], which supports the integrity of the economic space of the Russian Federation and its regions. (The Strategy of Spatial Development of the Russian Federation for the period up to 2030 was approved on December 28, 2024.) Therefore, the metasystem approach presented by Cand. Sci. (Phys.–Math.) *A.N. Solomatin* (Federal Research Center "Computer Science and Control" RAS) can be a useful principle for the formal description of this relation; for details, see his paper "Metasystems in the Strategic Management of the Region." He noted the increasing relevance of the mathematical method of regional programming against the background of the growing role and independence of regions in the process of globalization. Being developed in FRC "Computer Science and Control" RAS, this method formalizes the matrix models of strategic planning and the maps of strategic groups of competitors and strategy formation to build multi-level models of a region. Moreover, the author proposed to replace the conventional "system–environment" pair for regional economy's objects with metasystems covering a set of interacting objects of the micro-environment. In this case, each object is treated as a vector in the multidimensional space of its characteristics, and all objects are visualized to reflect their development and interaction with other objects.

When developing the concept of metasystems formation, it is advisable to follow the Methodological Recommendations for Elaborating and Correcting the Socio-economic Development Strategy of a Subject of the Russian Federation and the Action Plan for Its Implementation.[6] According to these recommendations, one should use a universal conceptual basis with the following typical elements: risks; target scenario; priorities of the subject's development; external and internal development factors; the correction, change, and actualization of the Strategy; resources; tangible and intangible assets; the result of socio-economic development, etc. The above concepts formalize the competitive advantages and economic specialization of a federal subject and its potential as well as the problems and prospects for the development of the main industrial complexes expected to be placed on the territory of the subject, etc. In this case, there arise great prospects for megaprojecting to integrate different aspects of the strategic planning of federal subject's development, including infrastructural, technological, spatial, and others.

The successful implementation of megaprojecting presupposes the development of tools for modeling and management of investment processes. This problem was discussed in the plenary paper "Analysis and Management of Large-Scale Programs under Sanctions" by Dr. Sci. (Eng.) *V.K. Akinfiev* (ICS RAS) [15]. The author analyzed the situation in Russia after the introduction of economic sanctions in 2022, when the national strategic priority of the Russian Federation shifted toward ensuring the technological sovereignty and structural adaptation of the economy. Against this background, in the coming years, the Russian Government plans to launch 12 megaprojects in critical sectors of the economy based on a universal project management mechanism to be developed on the following principles: public-private partnership, guaranteed demand, a cluster investment platform, and reliance on state support measures (the agreement on the protection and promotion of capital investments and special investment contracts). The paper demonstrated the solution of this problem on the example of the comprehensive development program of the air transport industry of the Russian Federation until 2030, which is based on the TEO-INVEST software complex.

With scientific and technological progress as a leading factor of economic growth, the Strategy for the Scientific and Technological Development of Russia becomes the most important document. To make the right investment decisions in due time under rapid technological changes, one should orient in the variety

[5] Decree of the President of the Russian Federation dated May 7, 2024, no. 309 "On the National Development Targets of the Russian Federation for the Period up to 2030 and in the Perspective until 2036." URL: https://docs.cntd.ru/document/1305894187 (Accessed December 16, 2024.)

[6] Order of the Ministry of Economic Development of the Russian Federation dated March 23, 2017, no. 132 (as amended on February 18, 2022) "On Approving Methodological Recommendations for Elaborating and Correcting the Socio-economic Development Strategy of a Subject of the Russian Federation and the Action Plan for Its Implementation." URL: https://docs.cntd.ru/document/456054578 (Accessed May 15, 2024.)

of possible trajectories of national breakthrough development. In this context, Dr. Sci. (Econ.) *O.S. Sukharev* (Institute of Economics RAS) presented his paper "Technological Development of Russia: Achieving Sovereignty" [16]. The author proposed an original approach to forming economic policy based on the concept of cumulative effect and distributed management. His theory differs from conventional views on economic policy, as the emphasis is placed on the analysis of parameters characterizing technological development. The main thesis of the paper is that economic policy should aim at harmonizing the structure of targets, instruments, and factors with the economic structure. To implement this idea, the author introduced equations linking key targets, including economic growth and inflation, with various factors. Concretizing the factors yields equations for the impact of instruments on them and their relationship with economic structure dynamics. Additional equations may be required to reflect the interaction of instruments with each other and the possible collinearity of targets.

In modern conditions of tense geopolitical and geo-economic conflicts, there arises an acute task of developing innovative information technologies to identify sources of misinformation dissemination in the networks of public discussion of state strategic planning documents. In this regard, special attention was drawn to the plenary paper "On the Influence of Bots and Content Moderation on User Opinions in Social Networks" by Dr. Sci. (Eng.) *D.A. Gubanov* and Dr. Sci. (Phys.–Math.) *A.G. Chkhartishvili* (ICS RAS) [17].

In their study, the authors proposed an approach to information control based on modeling opinion dynamics in social networks. In conventional models, by assumption, an agent (network user) translates his/her internal state and opinion without distortion.

To investigate the effectiveness of network confrontation organized using bots, the authors introduced a model of information cascades representing a sequence of comments on social media posts. In such models, the true opinions of users on certain issues are not obvious, and their actions do not always reflect genuine interests. Note that bots act as first commenters. Computational experiments were carried out, and the following conclusions were drawn accordingly: the cascade of misinformation is significantly influenced by several model parameters, namely, the number of bots, their ranking algorithm, and the strategies of the players (the administrator and bots). This model can be used to identify the sources of misinformation dissemination in social networks and design effective block mechanisms for such sources.

The accelerated growth of industries, technologies, and productions of the new technological mode can be significantly promoted by R&D results in the field of control computers, mathematical methods of modeling and operations research, and hybrid methods of system dynamics. The following papers are some examples of promising achievements.

- The plenary paper "Calculations Features in Problems of Aircraft and Spacecraft Groups Management" (Dr. Sci. (Eng.) *V.P. Kutakhov*, Dr. Sci. (Eng.), Prof. *G.M. Alakoz*, and Cand. Sci. (Eng.) *S.I. Pliaskota*) described the competitive advantages of subprocessors with transforming associative memory [18].
- The plenary paper "Hierarchical Compromise" (Dr. Sci. (Eng.) *F.I. Ereshko*) demonstrated the application of game theory in practical strategic planning [19]. The author proposed a Pareto-based decision model for the two-level interaction of players. As shown in the paper, this model is applicable to studying interstate economic and environmental interactions to form a system of balanced relations.
- The plenary paper "From Digital Management Platform Development to a Computer-Aided Crop Rotation Engineering System in Agriculture" (Dr. Sci. (Eng.) *V.I. Medennikov* (ICS RAS)) was devoted to the development of a mathematical model of crop rotation system optimization implemented in a digital platform for industry management [20]. The author showed that in a digital economy, crop rotation should be the focus of precision agriculture, which is the basis of all agricultural processes.
- Note the sectional papers of ICS RAS employees on the latest methods of intermittent control, including "The Method of Dynamic Compensation in the Control Theory" (Drs. Sci. (Eng.) *S.A. Kochetkov* and *V.A. Utkin*) [21], "Analysis of the Behavior of a Three-dimensional Epidemic Model" (*O.S. Tkachev*, Cand. Sci. (Phys.–Math.) *M.S. Vinogradov*, and Dr. Sci. (Eng.) *A.V. Utkin*) [22], and "Dynamic Differentiation of Deterministic Signals of One Class" (*J.G. Kokunko* and *D.V. Krasnov*) [23].
- Note the sectional papers on system dynamics methods for recognizing critical event combinations of events, reducing the dimension of multicriteria optimization problems based on the particle swarm optimization model, and recognizing objects in video streams, including "The Influence of Critical Event Combinations on the Accuracy of Determining Damage from Atmospheric Pollutants" (Cand. Sci. (Eng.) *E.V. Kushnikova*, Dr. Sci. (Eng.) *V.A. Kushnikov*, and Dr. Sci. (Eng.) *A.S. Bogomolov* (Saratov Scientific Center RAS), and Dr. Sci. (Eng.), Corresponding Member of the RAS *A.F. Rezchikov* (ICS RAS)) [24], "Efficiency Comparison of Feature Processing Methods in Early Diagnostics Using Artificial Intelligence" (Dr. Sci. (Eng.) *G.S. Veresnikov*, *A.V. Golev*, and *A.V. Skryabin*) [25], and "Improved Detection of Related Objects

on the Example of Human Re-Identification Task" (*K.D. Rusakov* (ICS RAS)) [26].

Summarizing this brief overview of the papers, we note that MLSD'2024 participants have, in fact, functionally shaped a digital analytical support platform for the strategic planning of the Russian economy's long-term development.

The best papers were named at the closing session. O.I. Dranko, Chair of the session, thanked the authors, keynote speakers, members of the Program Committee, reviewers, and members of the Organizing Committee for their work, which largely predetermined the conference success.

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