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14TH INTERNATIONAL CONFERENCE ON MANAGEMENT OF LARGE-SCALE SYSTEM DEVELOPMENT (MLSD'2021)

The 14th International Conference on Management of Large-Scale System Development (MLSD'2021) was held on September 27–29, 2021. This conference is organized annually by Trapeznikov Institute of Control Sciences, Russian Academy of Sciences (ICS RAS), with the support of the IEEE Russia Section. The conference aims to promote international R&D cooperation on various managerial aspects of large-scale system development at sectoral, regional, national, and transnational levels.

Due to the ongoing restrictions imposed by the COVID-19 pandemic, the last two conferences, MLSD'2020 and MLSD'2021, were held online.

Leading scientists from academia, research institutes, universities, governmental and commercial organizations, professionally involved in the theory and practice of management in the modern era of the information society, took part in the MLSD'2021 conference.

The conference program included original research results in the following sections:

Section 1. Problems of managing 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. Managing the development of a digital economy. Design offices, situational and prediction and analytical centers, institutes of large-scale system development.

Section 4. Simulation and optimization in problems of managing large-scale system development.

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

Section 6. Managing the 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 nuclear power objects and other objects of increased danger.

Section 12. Infoware and software for management systems of large-scale production.

Section 13. Methodology, methods, software, and knoware for big data processing and intelligent analysis.

Section 14. Monitoring in managing the development of large-scale systems.

Section 15. Managing the development of large-scale health systems, biomedical systems, and technologies.

Section 16. Managing the development of social systems.

According to the schedule, the conference was held over three days. On the first day, there was a plenary session; on the next two days, sectional sessions.

In total, 255 papers were presented at the conference. Amongst them, 153 papers were selected, extended, and published electronically in IEEE *Xplore*; please visit https://ieeexplore.ieee.org/xpl/conhome/9600061/proceeding. Also, several papers were recommended for publication in *Automation and Remote Control*, *Control Sciences*, and other scientific journals.

The central theme of MLSD'2021 was elaborating a model-oriented approach to system analysis of large-scale systems based on the meta-model of the developing system of developing systems (DSDS). The DSDS meta-model generalizes the classical concept of "the system of systems," bringing to the forefront the life cycle management of each system (development, application, modernization, and disposal). The new view on systems analysis forms the requirements to the information sources involved, extends the key indices and indicators of development, initiates the development of software engineering of network situation modeling, forecasting, and goal-setting. The role and scope of DSDS-class modeling and meta-modeling are increasing significantly against the background of total digitalization and interdisciplinary globalization of management. Ideas of this circle permeate the papers presented in the plenary session and were further detailed in different directions during the sectional sessions.

The **plenary sessions** with all conference participants usually feature guest speakers who address the most pressing issues and present new solutions for managing large-scale systems development. This year's plenary session was very rich and heated. The plenary program of MLSD'2021 was almost entirely devoted to promoting a model-centric strategic planning style in the era of the digital revolution and digital transformation of the economy. Two groups of the most striking plenary papers aroused great interest and active discussions. In the first group, five plenary papers were devoted to generally significant problems of digital strategic planning; in seven papers of the second group, these problems were considered from the sectoral perspective.

The first group included the following plenary papers:

- "Management of large-scale systems development under new conditions" by Dr. Sci. (Eng.), Prof. *A.D. Tsvirkun* (ICS RAS). The paper considered the digital transformation problem of large-scale systems, listed by the Government of the Russian Federation among strategic activities. Based on system model-oriented research, the author presented a holistic and interlinked strategic planning methodology for large-scale systems development. The methodology involves the classical definitions and concepts necessary to digitize algorithms, technologies, and methods of forecasting the development of systems characterized by complex (intersectoral, interregional) interaction of elements, distributed over a large territory, and requiring substantial resources and time. The methodology takes into account several distinctive features of such systems: dynamism (incoming raw materials, continuous technological operations, transport flows, funding with material and financial resources, depreciation, etc.); the presence of uncertain and uncontrollable factors, the need to manage risks (insurance, loss of competitiveness, reduced financial and economic potential, etc.); the complexity of balanced multilevel and multicriteria goal-setting and an appropriate strategy of goal-achievement; the use of sectoral, intersectoral, regional, national, and transnational classifiers and standards, etc. The author described TEO-INVEST, a software package for the feasibility study of investment strategies built on the prospective principles of project-program and aggregate-decomposition approaches. This theme was further revealed in the papers of Sections 1 and 2, devoted to the key areas of development and their solutions through investment projects and programs.
- "Large-scale projects in the strategic planning system of the Russian Federation" by Dr. Sci. (Econ.), Prof. *V.G. Varnavskii* (ICS RAS). The paper considered the fundamental problems of coordinating different incentive strategic development mechanisms (resource, technological, and institutional). The advantages and disadvantages of the modern normative base for strategic planning in the Russian Federation were analyzed in detail. Particular attention was paid to the transport sector. Priority large-scale investment projects in this sector for the period up to 2030 were highlighted. A strategic planning management system with the public-private partnership was proposed.
- "Oil market: modeling problems" by Dr. Sci. (Eng.) *V.K. Akinfiev* (ICS RAS). The paper is an important supplement to the strategic planning methodology of large-scale systems development based on the model-oriented approach. The problem of oil market modeling was considered, and mathematical models of oil market forecasting were surveyed. The competition between conventional and shale oil producers was modeled to assess the effects of the OPEC+ agreement. The prospects of the oil market development after 2020 were considered under possible scenarios for implementing the energy transition policy.
- "Management problems in large-scale projects of the mixed economy" by Dr. Sci. (Eng.), Prof. *F.I. Ereshko* (Dorodnicyn Computing Center, Federal Research Center "Computer Science and Control" RAS) and his co-authors *A.Yu. Mushkov* (All-Russia Scientific and Research Institute "Center"), *N.I. Turko* (State Corporation Rostec, Academy of Military Sciences), and Dr. Sci. (Eng.), Prof. *A.D. Tsvirkun* (ICS RAS). The paper presented the authors' research on the management of large industrial infrastructure systems within the global digitalization trend of the economy. The initial foundations of the research and development were described, and domestic experience in using mathematical models, information and communication technologies, and large volumes of information in management systems was surveyed. The issues of centralization and decentralization of management in complex systems were considered. Theoretical decision-making for assessing the prospects of state-business partnership development within the existing legal norms was given. A block of conceptual models corresponding to the planning level of large-scale organizational systems was presented. The issues of data preparation, algorithmic software development, and the combination of macro- and micro-descriptions of economic systems were considered.
- "Breakthrough development toolkit and its applicability in the first phase of implementing the unified national development plan" by Dr. Sci. (Eng.), Prof. *V.A. Irikov* (Moscow Institute of Physics and Technology) and his co-author, Cand. Sci. (Phys.–Math.) *N.S. Biryukov*. The paper noted the special role of the breakthrough development toolkit as a non-standard mechanism for implementing national pro-

jects and achieving ambitious goals, such as a multiply increased growth rate. A scheme was proposed to identify bottlenecks and eliminate them at minimum cost using a trajectory model and system optimization algorithms. Measures to eliminate bottlenecks hindering the required growth were elaborated and ranked as follows: (1) the creation of a program and an annual, quarterly comprehensive action plan for breakthrough development; (2) the development of a unified and goal-oriented multilevel automated system for preparation, adoption, and execution of decisions; (3) the provision of timely and complete managerial feedback information on the implementation of local development programs and actual results; (4) management of the policy of training qualified personnel and teams capable of developing and implementing effective and efficient tools of targeted management of breakthrough innovation development; (5) management of deficit-free federal and regional development budgets, etc.

The second group included the following plenary papers:

- "Transformation of electric power systems: directions and problems" by RAS Corresponding Member *N.I. Voropai* (Melentiev Energy Systems Institute, Siberian Branch RAS). The paper presented a methodology for justifying the development of the electric power sector and electric power systems and companies. The methodological basis of the approach was stated. Models and methods for forming and studying electric power sector development conditions and models and methods for justifying electric power systems development are given. Power consumption management features and models and methods for studying the influence of liberalization relations on the development of the power sector were considered. The basic knoware and software tools for solving these problems were described.
- "A conceptual design of a simulation complex to manage the operation and development of the hydrogen energy sector" by RAS Corresponding Member A.F. Rezchikov (ICS RAS) and his co-authors, Drs. Sci. (Eng.), Profs. A.D. Tsvirkun and O.I. Dranko (ICS RAS), Dr. Sci. (Eng.), Prof. V.A. Kushnikov (Institute for Problems of Precision Mechanics and Control RAS), Dr. Sci. (Eng.) A.S. Bogomolov (Saratov State University), and Cand. Sci. (Eng.) I.A. Stepanovskaya (ICS RAS). The paper covered information and analytical support for developing a new digital economy sector (hydrogen energy), a topical problem attracting the scientific community's attention worldwide. The national hydrogen programs aimed at decarbonization of sectors by 2050 were surveyed. As a result, the authors proposed the concept of systematic model-oriented analysis tools for national roadmaps integrated into the hydrogen energy security lifecycle (production, storage, transportation, trade, consumption). The approach to strategic forecasting, planning, and control is based on the advanced principles of neural mapping from GIScience. This theme was further reflected in the sectional papers of management system dynamics, a scientific school developed in ICS RAS jointly with IPPMC RAS, Saratov State University, and Belarusian State University. The range of papers under consideration described computational methods for solving several large-scale strategic analysis and management problems: minimization of losses from harmful effects of industrial and vehicular pollutants; the structural design of network management for hydrogen fuel transportation; network management for hydrogen fuel supply to vehicles; control of possible deviations in the main national economic indicators under the influence of hydrogen energy development, etc.
- "A complex of strategic management models for large-scale transport infrastructure" by Dr. Sci. (Eng.), Prof. *V.V. Tsyganov* (ICS RAS). The paper considered a topical problem: the globalization of transport infrastructure management to increase the efficiency of the economy's real sector and Russia's socio-economic and spatial development. The author hypothesized that the strategic development of macroregions is impossible without the advanced development of transport infrastructure in the changing environment. This hypothesis characterizes theoretical and methodological foundations, methods, technologies, and components of the complex of strategic management models for large-scale transport infrastructure development. Within the proposed complex, five functional subcomplexes of models were developed to simulate and maintain practical processes of transport infrastructure development support: managing strategic development; selecting and examinating large-scale development projects; training and adapting; forming transport corridors; ensuring safety. As an illustrative example, the complex was applied to the strategic management of transport infrastructure development in Siberia, the Far East, and the Russian Arctic.
- "Strategic management of low-carbon development of the electric power sector in Russia: problems and opportunities" by Cand. Sci. (Econ.) *F.V. Veselov* (Energy Research Institute RAS). The paper revealed multidimensional modeling in the strategic energy planning loop, covering energy systems and energy markets, perspective development of the power sector and energy complex, and market mechanisms of development management in the energy sector. The author identified power sector development problems solved using the models: long-term forecasting of power sector development; ensuring technical and economic competitiveness of various energy technolo-

gies and modeling changes in the technological structure of the power sector; assessing investment strategies, performing financial and economic analysis, and predicting conditions for the sustainable investment and development of energy-related sectors and companies; modeling and assessing the effects of liberalization and restructuring in the power sector; elaborating mechanisms to manage development in a competitive environment; studying integration effects for electric power markets; optimizing conditions for the operation and development of the electric power sector within the single market; simulating greenhouse gas emission scenarios in the energy sector; analyzing technological possibilities, mechanisms, and consequences of the economic regulation of greenhouse gas emissions; examining the prospects, trends, and effectiveness of the development of intelligent energy, active consumers, and distributed power generation in the Unified Energy System of Russia.

- "Studies on forming an unmanned aerial vehicle complex as a large-scale system" by Academician of the Russian Academy of Rocket and Artillery Sciences *V.P. Kutakhov* (National Research Center "Zhukovsky Institute") and his co-authors, Dr. Sci. (Eng.), Prof. *R.V. Meshcheryakov* (ICS RAS) and *A.L. Smolin.* As noted by the authors, unmanned aerial vehicles have the prospects of continuous improvement and modernization due to their high science intensity and expanding range of applications. This determines the relevance of developing a digital model-oriented strategic design platform. The proposed approach is based on a canonical ontological model of an unmanned aerial vehicle complex that implements the concept of a distributed hybrid working environment with wireless communication between stationary and mobile network agents. The advantage of such a model is focusing on software engineering of digital tests of system breakthrough solutions covering materials, propulsion systems, onboard equipment, and communication and information exchange systems in ill-structured collaborative structures. The topics raised by the authors were developed quite extensively in the sectional papers, including sharing the experience of participation in the Aerobot 2020 competition, monitoring concepts, and proposals on the configuration management of unmanned aircraft systems, etc.

- "Considering regional peculiarities in the strategic management of agro-industrial integrated formations in the single digital interaction space" by Dr. Sci. (Eng.), Prof. *V.V. Kulba* (ICS RAS) and Dr. Sci. (Eng.), Prof. *V.I. Medennikov V.I.* (Dorodnicyn Computing Center, Federal Research Center "Computer Science and Control" RAS). The paper considered a mathematical strategic planning model of agro-industrial integrated formations under the digital transformation of enterprises within the requirements of complementarity theory (long-term partnership). As shown by the authors, formation planning strategies on a single digital platform lead to a flexible management system for the relations between farm producers and processing, servicing, marketing, and trading enterprises: everyone "sees" all the participants in the chain, up to the end consumer. The growth of agro-industrial integrated formations, including agricultural holdings, poses the problems of effectively integrating material, labor, financial, and information resources. Examples are the complete absorption of enterprises or the preservation of production and social integrity with possible independent actions in the economic and legal space. The proposed digital platform incorporates significant regional factors in the model: investment in production, human capital, and the management system considering the territorial logistics component; regional competitiveness strategies. The authors demonstrated that the global agriculture digitalization trends are shifting towards the concept of a single digital platform of integrated formations; under certain conditions, they will become a single platform of the entire agro-industrial complex.

- "Control of the dynamics of multidimensional opinions in social networks" by Cand. Sci. (Eng.) *D.A. Gubanov* and Dr. Sci. (Phys.–Math.) *A.G. Chkhartishvili* (ICS RAS). The paper was concerned with developing a strategic technology of digital society, represented by the concept of control in social networks (e.g., for designing new strategies with maximum public support). The paper considered the following situation: a control subject (Principal) applies an informational impact on agents. The Principal's strategy is to choose the interval of this informational impact (the initial and terminal instants). The Principal's goal (payoff) is to minimize the distance between the average opinion of all agents and its position. A model of opinion dynamics in social networks was presented. The model has two interrelated information processes: the spread of activity and the formation of opinions. The following problem was formulated and solved for this model: choose a Principal's impact strategy that eventually gains the greatest support in the social network. According to the authors, promising lines of further research are the analysis of optimal control actions for different values of the structure and dynamics parameters and consideration of informational confrontation. This new direction of large-scale management was considered in detail by several papers of Section 16. In particular, the spread of coronavirus information, the increased effectiveness of advertising activity, street protests, and other issues were studied therein.

Sectional sessions of the conference traditionally serve as a platform for discussing management problems of large-scale systems development in the sectoral and instrumental-methodological context. The sectional program of MLSD'2021 continued studies of the model-oriented approach to the strategic design of large-scale systems towards developing digital twins of enterprises, products, technological processes, production, etc. Conceptually, a digital twin is a multi-connected set of end-to-end technologies with a formal description of real-world objects to predict the twin's properties, functions and behavior, response to perturbations, and interaction with other digital twins. The papers presented on this topic can be divided into projects, models, and methods.

The development of digital twins at the project level was the subject of the following papers:

- "A distributed software development technology with virtualization and digital twins for process control systems of nuclear power plants" by Dr. Sci. (Eng.) *A.G. Poletykin*, Cand. Sci. (Phys.–Math.) *V.G. Promyslov*, Cand. Sci. (Phys.–Math.) *K.V. Semenkov*, *N.E. Mengazetdinov*, and Cands. Sci. (Eng.) *M.E. Byvaikov* and *V.N. Stepanov* (ICS RAS);
- "A study of the digital twin of an enterprise" by *A.N. Sytov*, *A.V. Vakhranev*, and Dr. Sci. (Eng.), Prof. *F.I. Ereshko*;
- "Models and methods of technological infrastructure management based on digital twins" by Dr. Sci. (Eng.) *G.G. Grebenyuk*, Dr. Sci. (Eng.), Prof. *G.N. Kalyanov*, Dr. Sci. (Phys.–Math.), Prof. *S.P. Kovalev*, Cand. Sci. (Eng.) *A.A. Krygin*, Dr. Sci. (Eng.) *O.V. Lukinova*, and Cand. Sci. (Eng.) *S.M. Nikishov*;
- "A module of analytical methods for minimizing repair cost on pipeline networks with forming an infrastructure digital twin" by Cand. Sci. (Eng.) *A.A. Krygin*;
- "Some peculiarities in the development and application of adaptive digital twins for managing large-scale high-tech production" by *M.V. Zenkovich*, Dr. Sci. (Eng.), Prof. *Yu.G. Drevs*, and *V.S. Inozemtseva*.

A large place in the development of digital twins is given to classical analysis techniques such as simulation and correlation models, discussed in detail on Section 4.

Services supporting digital twins in the strategic planning loop may include intangible assets accounting. Interesting new approaches in this area were presented in the papers of Section 3 (in particular, the ontologization of scientific discoveries, a unique digital platform for intangible assets, ratings as a digital benchmarking tool, and others).

The application of business intelligence methods to digital twins also seems promising. The methods of banking and financial systems presented in the papers of Section 6 can be a suitable tool here. They model inflation, optimize microfinance and lending, etc.

Nonlinear dynamic models of physical media and mechatronic structures under external factors are also significant for using digital twins effectively. These extremely important issues were considered on Section 5. The papers presented therein contribute to creating adequate simulation and optimization methods.

The data mining and monitoring methods described in the papers of Sections 13 and 14 can be used to manage the big data flows of digital twins.

In conclusion, let us emphasize the following: the papers presented at MLSD'2021 show a scientific groundwork for a uniform strategic planning scheme for developing large-scale systems with different applications. This approach enhances the integrated innovation processes envisaged by the state science and technology policy. Therefore, it seems appropriate to conduct further research to standardize and compile promising samples of digital models and twins.

Chair of the Organizing Committee
A.D. Tsvirkun

Secretary of the Organizing Committee
I.A. Stepanovskaya

Author information

Tsvirkun, Anatolii Danilovich. Dr. Sci. (Eng.), Trapeznikov Institute of Control Sciences, Russian Academy of Sciences, Moscow, Russia
✉ tsvirkun@ipu.ru

Stepanovskaya, Iraida Aleksandrovna. Cand. Sci. (Eng.), Trapeznikov Institute of Control Sciences, Russian Academy of Sciences, Moscow, Russia
✉ irstepan@ipu.ru

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Translated into English by *Alexander Yu. Mazurov,*
Cand. Sci. (Phys.-Math.),
Trapeznikov Institute of Control Sciences,
Russian Academy of Sciences, Moscow, Russia
✉ alexander.mazurov08@gmail.com