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Interdisciplinary competencies of managers for a technological breakthrough

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Abstract

The article aims to study the structure of and improve the model for the fostering of managerial competencies to solve the problems of a technological breakthrough in the domestic economy. The authors apply their proprietary approach that makes it possible to reveal the range of interdisciplinarity and to specify its content. Methods and tools for mastering the competencies in demand are developed. As the empirical base which proves the validity of their conclusions, the authors cite their own research as well as the results of the analysis of educational programs in engineering management implemented at the leading universities of the world, and the expert opinions of the heads of energy enterprises and professors of Russian universities. The paper analyzes the key factors in the formation of interdisciplinary competencies: a management paradigm towards which the educational process is oriented, a model of knowledge and skills that is adequate to the content of the tasks of a technological breakthrough, a methodology for analyzing interdisciplinary relationships in managerial decisions. The article outlines the relevant experience of training managers of various levels by the Department of Energy Management Systems and Industrial Enterprises of Ural Federal University.

The study is scientifically novel as it discovers a new approach to understanding interdisciplinarity when determining the managerial competencies necessary for a technological breakthrough. The practical significance of the article is due to the fact that it presents the experience of implementing the developed approach to the training of managers with an increased readiness to constantly embrace and implement future technologies.

Keywords: interdisciplinarity, interdisciplinary competencies, technological breakthrough, managerial education, proactive management, advanced learning, systems engineering, methodology for training managers.

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Introduction

The issue of applying an interdisciplinary approach in science, education, and practice has gained particular popularity over the past decade, characteried by an intense flow of technological innovations, an ever-increasing uncertainty of the context, and profound changes in political, economic and social foundations.

Interdisciplinarity, as noted in [Arbesman, 2015], is today found in almost everything. Of course, this trend can be considered a manifestation of academic fashion. However, if we look at the number of publications with the keywords "interdisciplinarity" or "interdisciplinary" in the scientific bases of the peer-reviewed literature from 2010 to 2021, it seems possible to clearly record the steady positive dynamics of the interest of authors and readers in this phenomenon (Fig. 1). It can be safely assumed that the trend towards interdisciplinarity will further intensify as the volume of new complex tasks grows, as knowledge differentiation and integration increases [Kodama, 2018].

By interdisciplinarity the authors understand the synthesis of knowledge from different fields of science and practice and the identification of new relationships between them, which make it possible to obtain qualitatively new solutions to complex problems. It is important to pay attention to the practical significance of this interpretation: due to the interdisciplinarity, it becomes possible to generate knowledge, without which it is virtually impossible to solve problems with a nonlinear, unclear structure in conditions of continuous change, uncertainty, and chaos. This statement is of particular relevance when aiming for a technological breakthrough, when it is necessary to create and quickly implement unique innovations simultaneously in a wide variety of industries and processes. Due to the mutual enrichment of scientific disciplines or areas of practical activity, completely new questions are identified and problems are formulated, the research results of which allow to obtain methodological tools, expand the horizon of science and increase the efficiency of practice.

In such axiomatics, a specialist, be it an engineer, a manager, an expert in information technology, must quickly navigate even in those areas of knowledge, markets and industries that were traditionally not “mandatory” for his field of activity. The scale, depth, and versatility of the expertise of a new generation professional are increasing dramatically today, which requires reflection in educational programs of different areas of training. Speaking about management education in particular, when training managers, it is important not only to demonstrate the possibilities of interdisciplinary methodology as a way to organise teamwork for a comprehensive analysis of the situation and improve heuristic efficiency, but also to equip them with an arsenal of appropriate decision-making tools [Chryssolouris et al., 2013; Carr et al., 2018; Gitelman et al., 2019; Professionals in competition.., 2021].

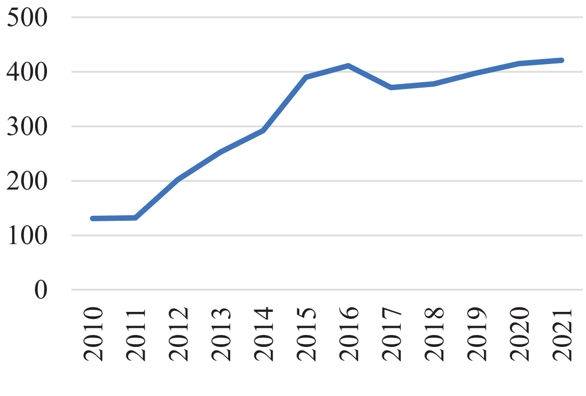
The purpose of this article is to identify the forms of interdisciplinarity and interdisciplinary competencies of managers that are especially significant for a technological breakthrough and to determine the most effective ways to form them. The author's approach to the definition of interdisciplinarity made it possible to identify the composition of the necessary interdisciplinary competencies and their relationship, which is important to take into account in the training of innovative managers.

1. Model of interdisciplinary competencies of managers for a technological breakthrough

The reduction of the "half-life" of professional knowledge and the avalanche-like growth in the volume of new information necessary for professional activity, on the one hand, and the limited time frame for the formation of new competencies, on the other, require constant analysis and restructuring of the conceptual model of competencies required in solving actual and predictable tasks. The growing complexity of tasks and the environment of managerial activity leads to the fact that instead of obsolete competencies, there is a need for modernised or completely new ones, which are characterised by a more interdisciplinary content and, accordingly, a more labor-intensive process of their formation.

Under the conceptual model of competencies, the authors mean the composition of clusters and the content of specific competencies included in them, integrated into a single system in accordance with their interrelations and dependencies and reflecting the ability of a professional to solve a certain class of tasks and problems. Such a system of competencies is a model of an educational program graduate, which determines the goals, requirements for the content and methodological organisation

Fig. 1. Dynamics of the number of publications containing the keywords “interdisciplinarity” and “interdisciplinary” in bibliographic databases:
a) in the Russian eLibrary database, b) in the international SCOPUS database



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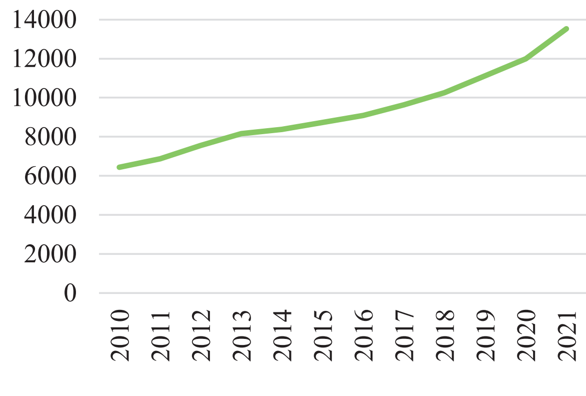


b)

of the educational process. The model should have a simple and illustrative form, convenient, readable and accessible for analysis and conclusions. At the same time, the first step in the transition from the model of a specialist to the process of its formation is the selection and full description of the complex of tasks that he must solve in his professional activity.

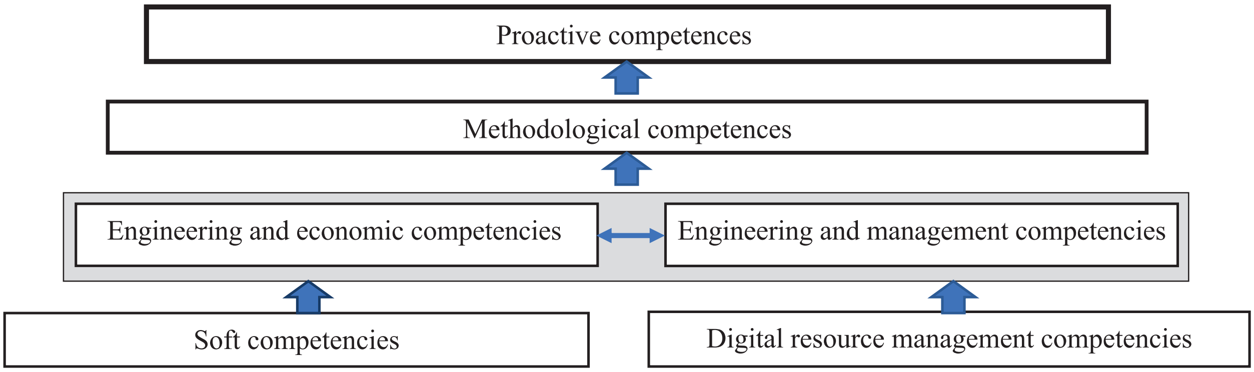
The structure and content of the conceptual model of actual competencies are determined by the management paradigm that the educational process is focused on in accordance with the understanding of the practical requirements for graduates of the management training program. Thus, the process of preparing a manager begins with the choice of a management paradigm and the development of a competency-based model of managerial activity corresponding to it.

The proactive control paradigm is the most appropriate for the tasks of a technological breakthrough. It determines not only the composition of competencies, but also their relationship and subordination, which are important to consider in the process of their formation. For this paradigm and, accordingly, a technological breakthrough, a suitable model is that includes the following clusters of managerial competencies: proactive competencies, methodological competencies, engineering

Table 1
The structure of interdisciplinary competencies of managers

Cluster competencies	Examples of specific competencies
Proactive measures	• Creation of systems for early detection of threats and opportunities • Concept design • Visual analytics • Designing the future of the company • Development of leadership strategies • Organisation of advanced training
Methodological	• Selection of tools for solving new problems, taking into account their interdisciplinary specifics • Development of integrated solutions at the intersection of management, engineering, economics, IT technologies, ecology, psychology, sociology • Conceptualisation of new scientific knowledge and technologies in the development of innovative projects • Assessment of the need to update their professional competencies in accordance with new interdisciplinary knowledge
Engineering-economical	• Economic evaluation of engineering solutions • Comprehensive analytics for solving breakthrough problems • Management accounting in interdisciplinary projects • Economic calculations and advanced business development models • Investment management in innovation engineering • Estimating costs and predicting the results of large projects • Assessing risks and resource efficiency
Engineering-management	• Organisation of technological modernisation processes • Project portfolio management • Support for technological entrepreneurship • Managing the interaction of employees, contractors, developers in solving complex problems • Organisation of network cooperation and distributed leadership
Digital resource management	• Digital remote control instruments • Application of Internet technologies in organisational activities • Technologies for the use of smart systems • Organisation of business processes in a virtual environment • Conceptualisation of technological process digitalisation
Soft skills	• Social, cross-cultural and interpersonal communications • Ability to collaborate productively and work as a team in a digital environment • Ability for self-development, self-learning and self-regulation • Ability to adapt and achieve results in a changing environment

Fig. 2. The logic of the formation of managerial competencies for a technological breakthrough in accordance with the subordination of their content



and managerial competencies, engineering and economic competencies, digital resource management competencies, soft competencies [Gitelman et al., 2020b].

This sequential list of competency clusters is a hierarchical structure, in which each of the clusters includes managerial abilities contained in the competencies below (Table 1).

In accordance with the understanding of the subordination and interrelationships of the main competencies of managers who are able to work in the proactive management paradigm, the optimal logic of their formation in training is determined (Fig. 2).

All these competencies are formed on the basis and to a large extent in the process of fundamental training, which creates a scientific understanding of the tasks and possibilities for their solution. Fundamental knowledge is the basis for the formation of interdisciplinary competencies, and the flexibility of thinking ensures the quality and dynamics of this process [Gitelman et al., 2022]. In turn, the formed interdisciplinary competencies develop the flexibility of managerial thinking and consolidate fundamental knowledge. Thus, the formation of abilities to solve interdisciplinary problems is closely related to the fundamental knowledge and flexibility of managerial thinking.

Let us give a generalised description of competence clusters discussed above.

Proactive competencies - the ability to anticipate changes in many heterogeneous factors, events and contexts, predict the future of the organisation and, based on this, develop solutions and proactive actions to adapt systems and business processes to anticipated and unpredictable changes.

In the competencies of preventive actions, research is highlighted, defined as the ability to see the need for additional study of certain issues and conditions of organisational and managerial activity, set specific tasks for applied research and organise its conduct, use the results obtained to make decisions, taking into account possible changes in the internal and external environment of the organisation.

Methodological competencies, as well as research competencies, acquire high significance with proactive management and organisation of advanced learning. They are abilities that allow you to develop a new vision and restructure your activities in connection with the emergence of fundamental changes in organisational systems. Theoretical training, flexible intellectual models and adaptive individual managerial strategies are necessary conditions for the formation of methodological competencies, which:

- expand the range of interdisciplinarity and the arsenal of systemic actions required to solve new complex problems;
- provide integrated solutions at the intersection of management, engineering, economics, IT-technologies, ecology, psychology, sociology and other scientific fields;
- establish and use the relationship between existing experience and new areas of activity, as well as new professions that become necessary to solve innovative problems.

Engineering and economic competencies (EEC) - the ability to use economic knowledge in evaluating the effectiveness of creating new technical and technological systems and their operation. The possession of these competencies is an indispensable condition for the work of a leader in order to make decisions regarding innovative activities.

Engineering and management competencies (EMC) - the ability to organise an active innovation process, the necessary organisational changes and the appropriate corporate culture, manage the life cycle of technological systems, improve internal and external communications, work with personnel (selection, motivation, professional growth and development of abilities), determine the priorities for the allocation of resources, taking into account the interests of stakeholders.

Unfortunately, in foreign publications, almost no attention is paid to the problems of the formation of EEC and EMC. The fact that managers need to know the basics of engineering and economics, as well as the fact that engineers need to master individual management tools, be able to work in project teams and understand the logic of entrepreneurship, seems indisputable today. With a deeper literary analysis, it turns out that specific tools for mastering the engineering and economic competencies of managers, their composition, and the required educational content are described very superficially.

Nevertheless, some generalisations regarding other views on the interpretation of these types of competencies can be made. So, EEC, as a rule, is understood as technical literacy, which is expressed in various attributes: the ability to "speak the same language" with engineering personnel, read the simplest diagrams and drawings, understand the composition and structure of the equipment of production systems, and, ultimately, based on this knowledge determine the economic component of certain engineering solutions [Childs, Gibson, 2009; Barrett, 2020; Klinbumrung, 2020]. The objective function of the EEC is formulated in [El-Baz, El-Sayegh, 2007] and is to help managers "expand" the production cycle into separate stages, evaluate the cost and predict the contribution of each of them to the overall financial result of the company.

As for EMC, they are a "consequence" of EEC and, according to a number of authors [Panuwatwanich et al., 2011; Pons, 2015; Jamieson, Donald, 2020], include a variety of decision-making skills regarding business development, taking into account the impact of the technological factor on the company's economy, its organisational structure, and market behavior model. Thus, EEC (first level competencies) only allow estimating the cost of certain production solutions, converting engineering developments, prototypes, rationalisation proposals into money, and EEC (next level competencies) provide an opportunity to create deeper projects of business transformations based on such an engineering and economic assessment.

The results of our research [Gitelman et al., 2020a; Gitelman et al., 2020b; Professionals in competition.., 2021] demonstrate a greatly increased importance in the management of complex production systems of EEC and EMC, which are based on knowledge of the latest technologies and their

Fig. 3. Taxonomy of basic digital competencies of managers

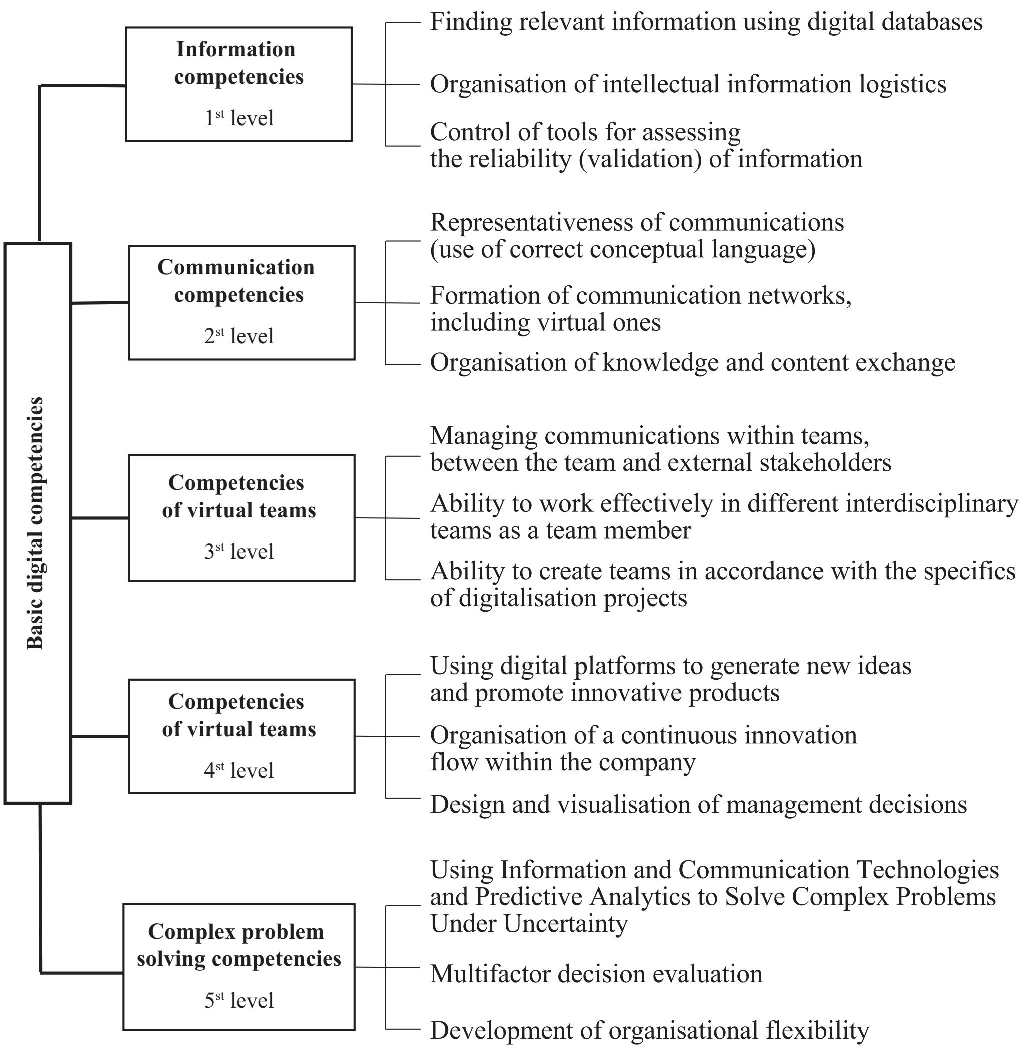
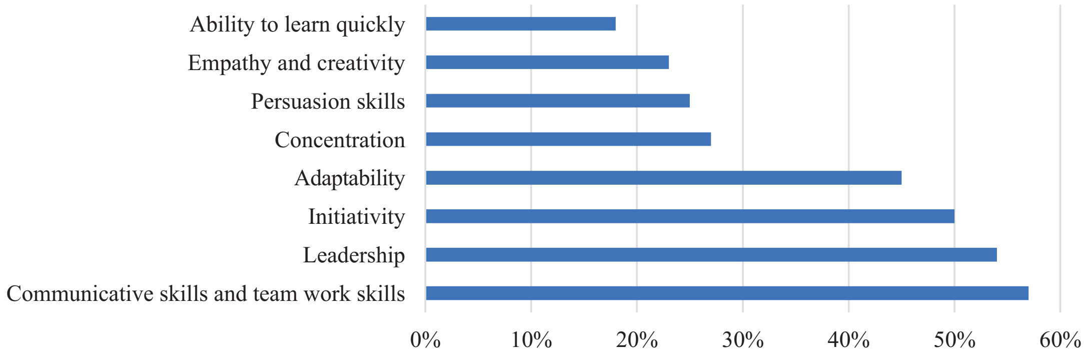


Fig. 4. The main soft skills of managers



Source: compiled by the authors based on [Training digital skills.., 2018; Apostolopoulos, 2020].

impact on the organisation of activities, business models, assessment of efficiency and risks, requirements for personnel. These competencies acquire particular importance during digitalisation: without mastering them, the manager will not be able to set specific substantive tasks for specialists.

Digital resource management competencies (manager's digital competencies) - the ability to work with complex information systems, large data sets and artificial intelligence, as well as rebuild business processes and organisational systems based on taking into account and using the capabilities of cloud technologies, the Internet of things, self-learning robotic complexes and smart environments.

Determining the content and structure of digital competencies is a highly relevant topic on the international research agenda [Van Laar et al., 2019; Oberlander et al., 2020; Van Laar et al., 2020]. In particular, E. Van Laar and colleagues [Van Laar et al., 2019; Van Laar et al., 2020] is attempting to create a taxonomy of digital competencies that includes five levels. The developers of the taxonomy assume that, without having mastered the first level competencies, it is impossible to fully master the second level competencies, and so on. (Fig. 3).

Digital competencies are based on digital skills - well-established behaviors brought to automatism based on knowledge and skills in the use of digital devices, communication applications and virtual networks [Training digital skills.., 2018].

Soft competencies (universal, soft skills) - the ability to act, carry out introspection and solve problems, taking into account the personal qualities of partners, the social environment, group and interpersonal interactions, which are similar in many areas and fields of activity. According to the results of a survey conducted by the developer of educational services Talent

Fig. 5. STEM concept in education

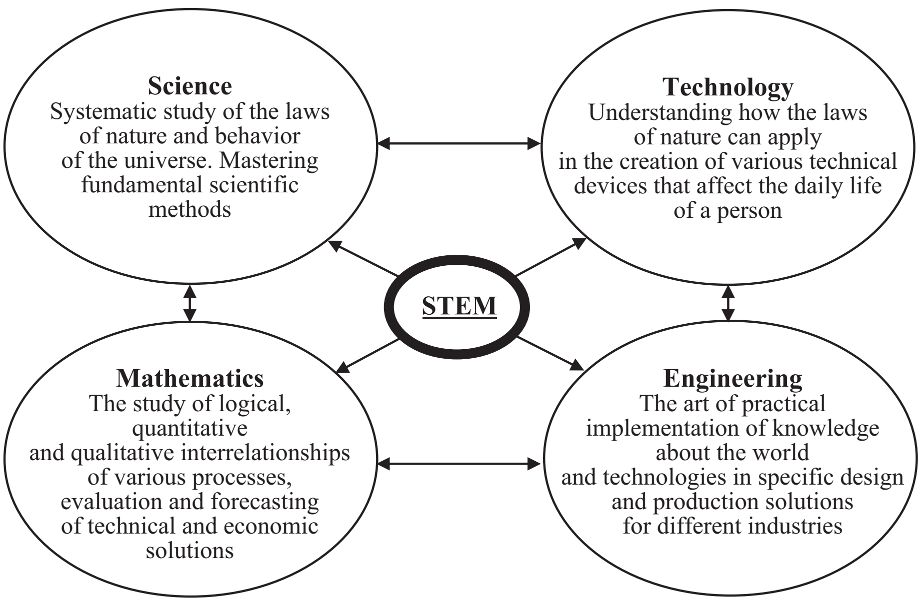


Table 2
Annual master's program in management in engineering from Duke University (USA)

Subjects	1st term	2nd term
Basic	Marketing Finance in the high-tech industry	Intellectual Property, Business Law and Entrepreneurship Management in the high-tech industry
Elective courses (4 at option)	Product development management Commercialisation of high-tech innovations Operations management Quantitative financial analysis Design thinking Customer Experience Design Artificial intelligence in action Marketing, analytics and research Data search and analytics Real-time data technologies Fundamentals of Data Science Fundamentals of Software Management (SW) Software Quality Management Competitive Strategies I Industrial Consulting Practice I Project Management I Management Decision Models I	Negotiations and sales Advanced finance for knowledge-intensive business Supply chain management Innovation management What's New in Big Data Analytics Data visualisation Principles and Applications of Machine Learning Intelligent Asset Management Uncertainty design and decision optimisation Product design Engineering Entrepreneurship Competitive Strategies II Industrial Consulting Practice II Project Management II Management decision models II

Table 3
Master's program "Management and engineering in the power industry" from
University of Aachen (Germany) + Maastricht Business School (The Netherlands)

1st term (Aachen)	Electrical Machines I Testing and diagnostics in complex systems engineering Energy transformations: fundamentals, topology, analytical tools Electricity storage and accumulation systems Entrepreneurial strategy Technological development strategy	2nd term (Aachen)	Electrical machines II High-voltage equipment in main and distribution electrical networks Automation in complex power systems Accidents and resilience of power systems Energy economics in the context of liberalised energy markets Finance and accounting (controlling) Electricity storage and accumulation systems - laboratory practice
3rd term (Maastricht Business School)	Global trends and sustainable business competitiveness Organisational development and transformation Management of international network projects business economics Responsible Supply Chain Management Human capital management	4th term (Aachen or Maastricht Business School)	Master's thesis preparation

LMS, soft competencies were identified that most employees of the surveyed companies need to develop (Fig. 4).

Of the soft competencies, one should single out the ability for teamwork, which every year is becoming an increasingly important and necessary element of a manager's professionalism, especially when solving the problems of technological modernisation and digital transformation of a business.

2. At the center of the current agenda are engineering-economic and engineering-management competencies

An analysis of world practice shows that these competencies are formed in conjunction in special programs in engineering management (Engineering Management), as a rule, implemented in the magistracy (although there are examples of both bachelor's and MBA programs in this area, and also a combination of a master's degree and MBA, as is done at Harvard University [MS/MBA: Engineering sciences, w.y.; Top 9 stem-certified.., w.y.]). The standard requirement for applicants to a master's program is a basic education in the STEM model (science, technology, engineering and mathematics) [Masters in engineering management.., 2021].

STEM refers to the concept of interdisciplinary problem-based learning that involves students in activities related to the design, development and operation of technological systems; open, case-oriented discussions on topical issues from the world of science, technology, social sphere; solving problems of specific industries and companies based on the application of fundamental knowledge about nature and the laws of technological development; team and individual work to solve problems of high uncertainty [White, 2014; Zaher, Damaj, 2018; Application trends.., 2019].

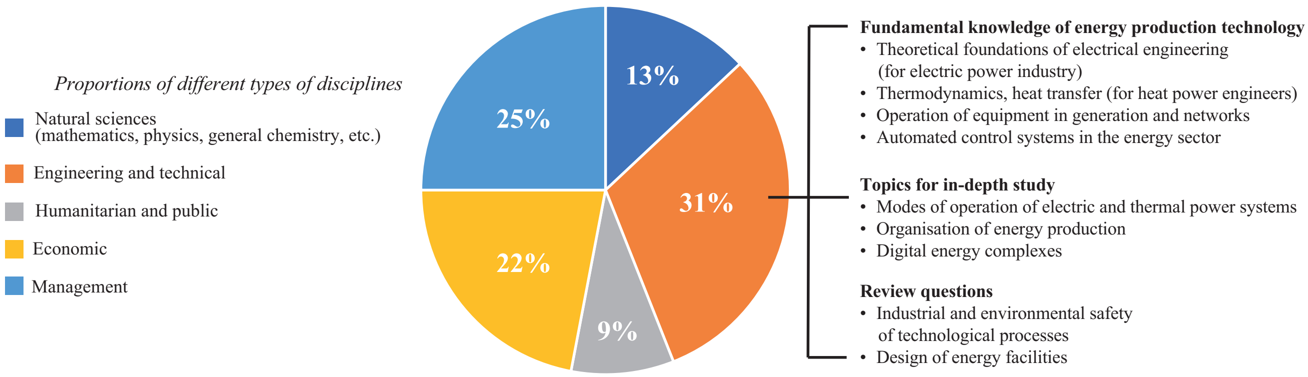
All elements of the concept are closely interconnected and organically complement each other. The semantic roles played by each of the elements in the educational process are shown in Fig. 5.

As the object of study becomes more complex and the qualifications of students grow, the proportions of STEM shift towards an increase in the Technology and Engineering elements [Application trends.., 2019]. In other words, the more complex the issues discussed and the more qualified the audience, the

Table 4
“System design and management” course examples (MIT)

Course type	Engineering	Management	Interdisciplinary
Basic	System analysis Computer systems design principles Statistics for engineers and research specialists Operations engineering	Strategic innovation management and entrepreneurship Introduction to operations management Competition in an unstable environment Economic analysis for decision making	—
Advanced study	Engineering of human-machine systems of business Engineering of distributed computer systems Resource support for production: energy, materials, processes Optimisation of logistics systems	Strategy for anticipating market changes Theory and practice of behavioral decisions Power and negotiations Business analysis Investment management Innovative business ecosystems	Manufacturing systems Design of logistics systems Risk based solutions
Elective courses	Sustainable energy in the context of climate change Biomaterials engineering Aerospace systems engineering Software engineering Systems engineering (Advanced) Cyber security Cognitive robotics Integrated microelectronics Materials engineering for clean energy Robotics	Strategic opportunities in energy Transformation of business models in the digital economy Financial data analysis and programming Leadership in uncertainty Data-driven communications Blockchain in business Game theory for competition for the future	Creative leadership teams Engineering, economics and regulation in the electric power industry Data analysis to create new value Innovation teams Business systems architecture Roadmaps for technological business development

Fig. 6. “Reference” structure of the educational program
for training energy managers



Source: Compiled by the authors based on the results of a questionnaire survey.

fewer hours in the curriculum are devoted to fundamental laws and applied methods.

An analysis of the curricula of Master's programs in Engineering Management, implemented at the world's leading universities (included in the top 100 international rankings QS and THE), allows us to distinguish three types of them.

1. Programs aimed at universal training of leaders. They include an average of 10-15 courses in the field of production, operational, IT management, sometimes with a focus on advanced technologies of the industrial revolution. The courses studied can be conditionally divided into two blocks: traditional (finance and economics, accounting, quality management, personnel management, operational management) and interdisciplinary with a focus on the technological aspect of business (systems engineering, development of innovations in engineering and management, information and analytical systems, business modeling, project management for the development of production and business) [Mesquita et al., 2015]. An example of a program of this type is shown in Table. 2.

2. Leadership training programs for specific industries with advanced technologies that play a significant role in the functioning and development of a business. The corresponding example is given in Table. 3.

3. Advanced programs focused on training innovative managers prepared for continuous development, testing and implementation of future technologies in engineering, IT, environmental security sector.

As examples of programs of the third type, we cite Stanford University (USA) and the Massachusetts Institute of Technology (USA).

The Management and Engineering program at Stanford University is built around six research topics that are directly integrated into the curriculum content at both the undergraduate and graduate levels: Computational Social Science, Decision Making and Risk Analysis, Operations Research, Organisational Management, Technology and Entrepreneurship, policy and strategy, quantitative methods of financial analysis. Among the main learning outcomes of the program: mastery of the mathematical apparatus, the ability to plan and conduct experiments, the ability to design complex systems (based on systems engineering tools).

At MIT, the Systems Design and Management program is built on the three-orbit principle. On the central orbit - basic courses in engineering and management (36 credits). On the second orbit - compulsory courses of in-depth study (in the amount of 12 credits in engineering + 12 credits in management). And, finally, on the third orbit - elective courses at the student's choice (Table 4). Students are required to earn a minimum of 30 credits, with a choice of engineering, management and interdisciplinary courses. The list of electives to choose from is significant: approximately 150 courses in engineering, 50 management and 30 interdisciplinary courses.

The practice of leading universities demonstrates an increased interest in engineering management, engineering and economic education. This is no coincidence: the production of the future, industry 4.0, is increasingly being put at the forefront. In Russian universities focused on complex high-tech industries (MEPhI, MAI, Moscow State Technical University named after N.E. Bauman, ITMO University and others), these issues are also given increasing attention when training managers and economists.

In complex high-tech industries, EEC are key competencies, since they ensure the functioning and development of the enterprise, its technical, technological and economic systems as a whole from the standpoint of improving reliability, safety, environmental and economic efficiency. EECs are in demand in substantiating and making managerial decisions in almost all areas of activity (logistics, finance, marketing, strategic management, etc.).

For example, in the power industry, as part of the fuel supply process at power plants, it is necessary to understand that the boiler runs on fuel of a certain quality, has strictly specific suppliers and prices. In financial activities, when planning

Таблица 5
Междисциплинарные взаимосвязи энергетического перехода
Table 5
Interdisciplinary relationships of the energy transition

Links	Subject of management decision making (examples)
Technology - economy	Electricity prices - a methodology for assessing indicators of the effectiveness of capital investments
Economy-technology	Technical and economic indicators of power plants - issues of reliability management, optimisation of power system modes
Technology-ecology	Various forms of environmental impact of power equipment
Ecology-technology	Ecological decision-making criterion in managing the development and operation of the electric power industry
Ecology-economy	Environmental payments - current costs in environmental protection equipment
Economy-ecology	Economic constraints, such as doubling prices to lower environmental regulations (compromise target)
Economy-society	The impact of electricity and heating prices on people's living standards and their satisfaction with energy policy
Ecology - residents of the region	The impact of the environment determined by energy equipment on the health of the inhabitants of the region

the budget of an energy company, it is necessary to know the relationship between the efficiency of power units and business results. Energy marketing involves rational behavior in the energy and capacity market of an active consumer - a customer of the energy system for the necessary services. It is not without reason that our survey of experts revealed the special importance of engineering and technical disciplines in the preparation of energy managers: according to the respondents, it is precisely such disciplines, organically interconnected with economic and managerial ones, that come to the fore in training and should occupy more than 30% of the teaching load (Fig. 6).

The problem of a shortage of specialists with EEC is significantly aggravated if it is considered in the context of scientific and technological progress on the side of electricity consumers - at a new stage of electrification, a characteristic feature of which is the integration of intelligent energy systems and power-consuming systems into single self-adjusting and self-regulating production complexes. Important effects of this electrification stage are structural and market: the emergence of new jobs and professions, the development of new markets and related technologies. For example, in transport, due to the advent of high-speed railways and smart automotive infrastructure, an explosive demand is expected in the next 5–7 years for chemists, scientists in the field of new materials, software engineers, industrial designers, urban economists, and service systems designers [Creating the clean energy.., 2013; Technology outlook 2025.., 2016].

In general, it can be noted that the trends of further changes in EEC specialists in the electric power industry are associated with a number of factors:

1) development of energy markets and increased competition;
2) introduction of intelligent energy systems;
3) business diversification and development of economic relations between energy suppliers and consumers.

3. Systems engineering as a methodology for using interdisciplinary relationships in management decisions.

An understanding of interdisciplinary relationships is especially required for managers of industries that are the most complex engineering and technical complexes, such as the electric power industry, the telecommunications sector, the nuclear and oil and gas industries, transport, and the military space sector. In these sectors, they are technologies in the broadest sense, from targeted research and engineering to innovation, that are the objects of concentration of interdisciplinary relationships [Schoemaker et al., 2013; Okhtilev et al., 2014]. Therefore, knowledge of the engineering foundations of production and scientific and technological trends is an indispensable condition for the ability of a manager to perform his functions successfully. Therefore, in management education, the volume and content of scientific and technical, engineering and technological, technical and economic training should be significantly strengthened, which will allow the manager to master the connections between technology, economics, ecology, the human factor [Gitelman et al., 2017], link professional knowledge with unique industry specifics.

Let us explain this thesis on the example of energy transition problem, which is extremely relevant for modern society - the movement of energy, related infrastructures and energy-consuming systems to a carbon-neutral model, implemented on the basis of structural and technological transformations that have environmental, economic and technological results.

Already from the very definition of the energy transition follows the objective need to identify the relationship between the technique and technology of energy production, energy economics, and environmental aspects of energy production (Table 5). In particular, we are talking about strengthening and new forms of technical and economic ties in the "supplier-consumer" aspect, including the quality and reliability of energy supply. Each of these relationships requires specific interdisciplinary competencies.

As a result of taking into account these interdisciplinary relationships, it is possible to develop integrated solutions that, in terms of content, are focused on:

- a comprehensive assessment of the results and consequences (technical, economic, social, environmental) of management decisions based on the analysis of all internal and external relations of the management object;
- consideration of all possible options for achieving the target results, differing in the combination of resources used, methods of their attraction and application;
- determination of technical and economic risks and uncertainty in obtaining the target results of a management decision.

Such solutions require a systematic approach, taking into account all non-linear relationships within complex systems, consideration from the standpoint of the full life cycle. In this regard, the most appropriate methodology for their adoption and subsequent implementation is systems engineering.

Systems engineering has entered engineering practice as a way to overcome the complexity of developed and maintained systems, as an interdisciplinary approach and as a tool necessary to create successful systems that can meet wants and needs of customers, users and other interested parties. The application of this approach allows us to reduce the risks and impact of system errors, to ensure interaction at the intersection of disciplines, where unforeseen difficulties most often arise.

Engineering disciplines are most closely related to a particular field of knowledge in which they specialise, and are less involved in the process of creating value. In contrast, systems engineering in the latest concepts [Systems engineering vision.., 2021] is less focused on a specific area of knowledge (mechanics, optics, chemistry, etc.) and to the greatest extent on the values and needs of stakeholders. At its core, systems engineering is interdisciplinary. To create a successful system, it is necessary to be a professional not only in at least one of the subject areas that define the system, but also to have sufficiently deep knowledge in other areas, to have the competence to communicate with specialists in various fields of science and practice, and to understand the needs of future users.

One of the founders of systems engineering - A. Sage - defined systems engineering as a management technology that is more related to technical leadership and system management, which determines the development of technologies, than to certain methods used to develop and maintain successful systems [Sage, Rouse , 2009]. At the same time, he distinguishes three levels of systems engineering. The lower level is the technology level that ensures the creation, use and maintenance of the system. The middle level is the level of methodologies that determines the direction of efforts and the coherence of the work of all project participants. The upper level is the level of system management, which ensures interaction with the external environment, the development of a strategy, and the choice of the direction of the organisation's development. Insufficient attention to the problems of this level negates all the efforts of the project team, dooming it to failure, despite the good elaboration of details and the coordinated activities of the participants.

All levels of systems engineering are interconnected and intensively exchange information. Each level has its own type of knowledge, which is also closely related. Knowledge of practices that accumulate skills and experience allows you to effectively and consistently act in standard situations and solve emerging problems in known ways. Knowing the principles that formalise problem solving allows you to cope with unexpected situations, work in conditions of uncertainty, develop new systems and practices. Knowledge of the prospects, both the directions of development of one's industry and related areas, and changes in the external environment, allows one to participate in the implementation of large projects, develop and maintain complex systems, and ensure the competitiveness of the organisation. Success requires all three types of knowledge and good organisation of the relationships between them, as well as continuous learning by doing and expanding existing knowledge.

System engineering processes involve the quantitative and qualitative formulation of goals, objectives and alternative solutions, the analysis of acceptable alternatives and the interpretation of its results from the standpoint of influencing the final result. These activities are performed iteratively as information and knowledge are accumulated, and provide solutions to problems as they arise. To perform these actions, systems engineering has an extensive arsenal of tools, which is replenished as systems become more complex and new problems are solved. Each level uses its own set of tools, but they are all integrated and coordinated with each other.

Each of the organisations that apply systems engineering methodologies adapts for itself a set of methods and tools used at the lower level (technology level). All of them have strong computer support and are closely associated with the systems

Table 6
Competences required during modernization

Competency	Required level		
	Engineer	Economist	Manager
Ability to formulate goals, prioritise, make adjustments when external conditions change	***	**	***
Ability to quickly respond to changing external conditions	**	**	***
The ability to catch signs of emerging problems and evaluate solutions before a negative effect manifests itself	***	***	***
Ability to assess the dynamics of change, select meaningful indicators, ensure correct measurement and analyse results	***	***	***
Ability to comprehensively assess the consequences of decisions made (analyse expected results from a business perspective)	***	***	***
Skills of constructive communication with external organisations, active exchange of information and reaching compromises	**	*	***
Ability to evaluate efficiency from the point of view of the entire life cycle	***	***	**
Ability to identify critical resources and ensure their efficient use	***	**	***
Possession of modern methods and tools for analysis and modeling	***	***	**
Ability to understand the needs and desires of customers and technically ensure their implementation	***	**	***

Note. Levels of development of competencies: * – initial (basic), ** – average (confidently owns), *** – highest (professional).

Table 7
Examples of training modules and interdisciplinary competencies formed in the master's program

Module	Type of formed competencies	Specific competencies as a result of training
Science-intensive technologies are the basis for the digitalisation of the industry	Engineering, economics and digital resource management	Development of an engineering project concept for a new product
Personnel and competencies for the digital economy	Soft	Professional self-development, build-up and use of creative potential. Solving complex organisational and managerial tasks based on the application of system analysis
Leadership in digital reality	Proactive Action	Development of business models and leadership strategies for businesses in the digital environment
Economy - finance - investment of innovative business	Engineering and economic	Application of analytical and financial investment tools in making proactive decisions
IT resources of innovative business	Digital resource management	Ensuring the interface of organisational systems with information technology
Startups and technology entrepreneurship	Engineering and management	Holistic vision of the system: trends - breakthrough technologies - promising markets - the intellectual potential of the organisation
Proactive management	Proactive Action	Creation of a system for early detection of new opportunities
Risks in the face of uncertainty		Formation of development concepts in conditions of uncertainty
Strategic context		Research and analysis of new markets and technologies

Table 8
Implementation of an interdisciplinary approach in training managers

Aims of professional training	Directions and methods of mastering interdisciplinarity
Management students Mastering basic knowledge. Ability to apply them in non-standard situations	• Areas of new scientific and technological achievements, industry technologies and understanding of changes in the content of management activities • Organisation of complex R&D using knowledge from different fields • Development of systemic, conceptual, strategic and cost thinking • Concept design • Business games, teamwork
Lower managers Understanding of management tasks and basic management systems. Ability to solve non-typical tasks for your level. Ability to work with people and small groups. Mastering the basics of value thinking	• Demonstration of the diversity and complexity of managerial knowledge (for engineering graduates) • Best practice training with case studies • Business games, strategic sessions, teamwork in solving engineering and management problems
Middle managers The ability to solve non-standard tasks for your level, analyse problem situations, formulate and solve problems. Development of systems thinking	• Integration of management knowledge into entire system • Training on best practices with case studies • Conceptual design of tasks for the development of their field of activity • Business games, strategic sessions, teamwork to solve innovative problems
Top managers Ability to integrate economic, industrial, environmental, political and cultural goals and solve complex problems. Identify and develop growth points, create breakthrough teams; organise large-scale transformations	• Shaping a vision for the future • Methods for generating business ideas • Behavior in extreme situations • Developing the ability to change vision, strategy and task priorities • Conceptual design of the future • Business games, strategic sessions, teamwork to solve the problems of developing and implementing a strategy

methodology, tied to the system life cycle processes and focused on priorities set at the top level.

The customer organisation needs to have employees who are able to interact effectively with designers, suppliers, as well as service organisations, so that the object being created is most consistent with the purpose, operating conditions and cost-effectiveness requirements. The technical personnel who will operate the facility must be trained during the process of developing, building and debugging the system. Other employees involved in the operation and maintenance of a new facility should not only understand its capabilities and features, but also ensure the most efficient use of assets and extend their life. At the same time, managers, economists, engineers need to master new competencies, which can practically be implemented in a team. For example, Table. 6 shows significant competencies common to all participants in the process of technological modernisation in the industry.

Local modernisation, associated with the replacement of equipment at an existing facility and bringing the infrastructure into line, also requires the use of systems engineering, although to a lesser extent. Nevertheless, most of those competencies listed in Table. 6 will be relevant in this case as well. Improvement of technology, replacement of individual units of installed equipment to extend the service life can generally be performed by traditional methods. However, even in this case, a comprehensive assessment of all the consequences, a comparison of different options for action in the context of strategic objectives and alternative technical solutions will be required. Therefore, most of the listed competencies will be required in this option, although not at such a high professional level.

It is important to emphasise that managers and engineers who are able to work in a single team and, therefore, have a common conceptual language, a holistic vision of the object of improvement, and who own the tools and means of network communications are becoming more and more in demand. In this regard, we note that in the programs for the management of engineering described above, focused on the training of innovative managers, issues related to systems engineering are given special attention. The use of systems engineering courses in the training programs for managers, economists, IT specialists is an increasingly common practice in foreign universities.

When preparing masters of management in the programs "Energy Business" and "Management of Innovations in the Digital Economy", the authors of this work have been implementing the original course "Systems Engineering for Managers" for more than five years. This course is aimed at mastering a systematic approach to solving managerial problems in the creation and development of complex systems in a dynamic environment. It is focused on the formation of systems thinking among masters, the development of system practices, solutions taking into account the interests of key stakeholders throughout the entire product life cycle. The course examines the development directions of systems engineering, providing an interdisciplinary approach to identifying and solving emerging problems that have no analogues in the past.

4. . Principles of formation of interdisciplinary competencies of managers

The formation of interdisciplinary competencies of managers is influenced by the following patterns of this process.

Managerial competence cannot be formed only in academic work within the framework of one discipline due to the multifaceted tasks of a manager. This requires training modules that include disciplines that provide individual structural elements of competence, and a project that forms its integral content.

The training module should contain educational, practical and project tasks that require the application of knowledge from all disciplines of the module, due to which interdisciplinary links are identified that ensure the integration of the studied content into the practical ability to solve specific problems.

This approach was used by the authors to develop training modules in the master's program, implemented using the original technology "Conveyor of Continuous Competence Development" [Gitelman et al., 2020c]. Each module is aimed at the formation of specific competencies corresponding to the competence model of the future industry manager (Table 7).

The goals and methods of interdisciplinary training of managers at different job levels differ from each other. So, for lower-level managers, the most important is the assimilation of the relationship between control systems and the ability to solve non-standard tasks. The priority for top managers is the formation of a comprehensive vision of the future, the development of competencies for large-scale transformations, human capital management, and the transformation of strategic priorities (Table 8). With each level of responsibility, the range of interdisciplinarity increases.

Conclusion

Management activity is becoming more complex and knowledge-intensive for many reasons, among which one of the main ones is the growth in the interdisciplinarity of new tasks, especially at the junction with engineering, which is especially noticeable in the light of the problem of a technological breakthrough. For this reason, many economic and managerial competencies well known to managers in modern practice are being transformed into engineering-economic and engineering-management competencies. Approximately the same thing happens with other competencies at the junction with other areas of knowledge, most often at the junction with information sciences when solving the problems of digitalisation of business processes. Fundamental changes in the content and methodology of professional training of managers are becoming necessary. Research and design-innovation tasks come to the fore, occupying a priority place in the content of academic disciplines and interdisciplinary projects in the modules.

Interdisciplinary competencies do not appear due to even a good command of disciplinary knowledge of all training courses. To achieve interdisciplinary learning outcomes, important implementations are necessary:

1) academic disciplines that reveal the relationship between different areas of knowledge and offer tools for their integration and practical use in project tasks;
2) research experience of joint issues and problems, showing the essence and importance of interdisciplinary connections and relationships;
3) the practice of applying interdisciplinary knowledge to solve real business problems, thanks to which they are transformed into managerial competencies.

The advanced experience of foreign and domestic management education convincingly confirms this.

It is very important that an understanding of the essence and significance of interdisciplinary issues for the successful activity of a manager is formed already at the first stages of managerial education. After all, as the career grows, the range and complexity of the interdisciplinary content in the work of a manager increases, and it becomes more and more difficult to master it at each higher level. Therefore, in the training programs for managers, especially master's programs, it is necessary not only to form interdisciplinary competencies, but also to teach the practices of their analysis, evaluation and self-development.

References

Gitelman L.D., Isayev A.P., Kozhevnikov M.V. (2020a). *Advanced management education for the industry of the future.* Ekaterinburg, Ural University Press. (In Russ.)

Gitelman L.D., Isayev A.P., Kozhevnikov M.V. (2020b). Reforming the management of education - condition of sustainable economic development. *Strategic Decisions and Risk Management,* 11(2): 116-131. DOI: 10.17747/2618-947X-2020-2-116-131. (In Russ.)

Gitelman L.D., Isayev A.P., Kozhevnikov M.V., Gavrilova T.B. (2022). Fundamental knowledge and flexibility of thinking as priorities of management education for technological breakthrough. *Strategic Decisions and Risk Management,* 13(2): 92-107. DOI: 10.17747/2618-947X-2022-2-92-107. (In Russ.)

Gitelman L.D., Kozhevnikov M.V., Ryzhuk O.B. (2020c). Technology of accelerated knowledge transfer for anticipatory learning of digital economy specialists. *Economy of Region,* 16(2): 435-448. DOI: 10.17059/2020-2-8. (In Russ.)

Digital skills education: Global challenges and best practices: analytical report (2018). Moscow, Sberbank Corporate University. (In Russ.)

Okhtilev M.Yu., Mustafin N.G., Miller V.Ye., Sokolov B.V. (2014). The concept of complex objects' proactive management: Theoretical and technological basis. *Proceedings of High Schools. Instrument Making,* 11(57): 7-15. (In Russ.)

Gitelman L.D., Isayev A.P. (eds.) (2021). *Professionals in competition for the future. Advanced learning for leadership in the digital industry.* Moscow, SOLON-Press. (In Russ.)

Apostolopoulos A. (2020). *Employee upskilling & reskilling statistics: Casting light on the trend.* Talentlms.com. https://www.talentlms.com/blog/reskilling-upskilling-training-statistics/.

Application trends survey report 2019. (2019). Graduate Management Admission Council (GMAC). https://www.gmac.com/-/media/files/gmac/research/admissions-and-application-trends/application-trends-survey-report-2019.pdf.

Arbesman S. (2015). *The deep interdisciplinarity of everything around us.* Wired.com. https://www.wired.com/2015/03/deep-interdisciplinarity-everything-around-us/amp.

Barrett C. V. (2020). *Engineering management competencies: A framework for present and future engineering environments.* Master of science thesis, engineering management & systems engineering, Old Dominion University. DOI: 10.25777/v6h6-8r34.

Carr G., Loucks D.P., Blöschl G. (2018). Gaining insight into interdisciplinary research and education programmes: A framework for evaluation. *Research Policy,* 47(1): 35-48. DOI: 10.1016/j.respol.2017.09.010.

Childs P., Gibson P. (2009). Management education for engineers. *20th Australasian association for engineering education conference, University of Adelaide,* 6-9 December 2009. https://ro.uow.edu.au/cgi/viewcontent.cgi?article=1029&context=gsbpapers.

Chryssolouris G., Mavrikios D., Mourtzis D. (2013). Manufacturing systems: Skills & competencies for the future. *Procedia CIRP,* 7: 17-24. DOI: 10.1016/j.procir.2013.05.004.

Creating the clean energy economy. Analysis of the electric vehicle industry, international economic development council report (2013). International Economic Development Council. http://www.iedconline.org/clientuploads/Downloads/edrp/IEDC_Electric_Vehicle_Industry.pdf.

El-Baz H.S., El-Sayegh S. (2007). Developing engineering management core competencies. *5th Latin American and Caribbean Conference for Engineering and Technology,* 29 May - 1 June 2007, Tampico, México. http://www.laccei.org/LACCEI2007-Mexico/Papers%20PDF/CI157_ElBaz.pdf.

Gitelman L., Kozhevnikov M., Ryzhuk O. (2019). Advance management education for power-engineering and industry of the future. *Sustainability,* 21(11): 5930. DOI: 10.3390/su11215930.

Gitelman L.D., Sandler D.G., Gavrilova T.B., Kozhevnikov M.V. (2017). Complex systems management competency for technology modernization. *International Journal of Design & Nature and Ecodynamics,* 12(4): 525-537. DOI: 10.2495/DNE-V12-N4-525-537.

Jamieson M., Donald J. (2020). Building the engineering mindset: Developing leadership and management competencies in the engineering curriculum. *Proceedings of the Canadian Engineering Education Association (CEEA) Conference.* Paper 30. DOI: 10.24908/pceea.vi0.14129.

Klinbumrung K. (2020). Engineering education management using project-based and MIAP learning model for microcontroller applications. *7th International Conference on Technical Education (ICTechEd7)*: 33-36. DOI: 10.1109/ICTechEd749582.2020.9101246.

Kodama F. (2018). Learning mode and strategic concept for the 4th Industrial revolution. *Journal of Open Innovation: Technology, Market, and Complexity*, 4(3): 32. DOI: 10.3390/joitmc4030032.

Masters in engineering management vs MBA: A checklist for choosing (2021). Colorado.edu. https://www.colorado.edu/emp/2021/10/27/masters-engineering-management-vs-mba-checklist-choosing.

Mesquita D., Lima R.M., Flores M.A., Marinho-Araujo C., Rabelo M. (2015). Industrial engineering and management curriculum profile: Developing a framework of competences. *International Journal of Industrial Engineering and Management,* 6(3): 121-131.

MS/MBA: Engineering sciences. Hbs.edu. https://www.hbs.edu/mba/academic-experience/joint-degree-programs/Pages/ms-mba-engineering-sciences.aspx.

Oberländer M., Beinicke A., Bipp T. (2020). Digital competencies: A review of the literature and applications in the workplace. *Computers & Education,* 146: 103752. DOI: 10.1016/j.compedu.2019.103752.

Panuwatwanich K., Rodney S., Kali Prasad N. (2011). Project management skills for engineers: Industry perceptions and implications for engineering project management course. *Proceedings of the 2011 AAEE Conference,* Fremantle, Western Australia, 569-575.

Pons D.J. (2015). Changing importances of professional practice competencies over an engineering career. *Journal of Engineering and Technology Management,* 38: 89-101. DOI: 10.1016/j.jengtecman.2015.10.001.

Sage A., Rouse W. (2009). *Handbook of Systems Engineering and Management.* USA, John Wiley and Sons, Inc.

Schoemaker P.J.H., Day G.S., Snyder S.A. (2013). Integrating organizational networks, weak signals, strategic radars and scenario planning. *Technological Forecasting & Social Change,* 80: 815-824. DOI: 10.1016/j.techfore.2012.10.020.

Systems engineering vision 2035. Engineering solutions for a better world (2021). Incose. https://www.incose.org/docs/default-source/se-vision/incose-se-vision-2035.pdf?sfvrsn=e32063c7_10.

Technology Outlook 2025 – The 10 technology trends creating a new power reality (2016). Arnhem, DNV GL.

Top 9 STEM-certified MBA programs (w.y.). Find-mba.com. https://find-mba.com/lists/other-top-business-school-lists/top-9-stem-certified-mba-programs.

Van Laar E., Van Deursen A.J.A.M., Van Dijk J.A.G.M., De Haan J. (2019). Determinants of 21st-century digital skills: A large-scale survey among working professionals. *Computers in Human Behavior,* 100: 93-104. DOI: 10.1016/j.chb.2019.06.017.

Van Laar E., Van Deursen A.J.A.M., Van Dijk J.A.G.M., De Haan J. (2020). Measuring the levels of 21st-century digital skills among professionals working within the creative industries: A performance-based approach. *Poetics,* 81: 101434. DOI: 10.1016/j.poetic.2020.101434.

White D.W. (2014). What is STEM education and why is it important? *Florida Association of Teacher Educators Journal,* 1(14): 1-9.

Zaher A.A., Damaj I.W. (2018). Extending STEM education to engineering programs at the undergraduate college level. *International Journal of Engineering Pedagogy,* 8(3): 4-16. DOI: 10.3991/ijep.v8i3.8402.

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Digital transformation strategy: Digital competencies of a railway engineer

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Abstract

Scientific and technological progress amid the process of global digitalisation has prompted the demand for professions in relevant fields such as logistics, analytics, agriculture, industrial manufacturing, transport, and primarily for engineering and technical workers. Russian railways require not only physical infrastructure, but also digital skills of its operation by engineering and technical workers in order to integrate into the digital economy. The aim of the article is to study modern requirements for the professional competencies of railway engineers, primarily their digital literacy and the ability to work with special software. The authors mention the need for an engineer to have softskills and hardskills. The article provides a list of the main software complexes that are included in the special digital competencies of a railway engineer.

The authors of the article through the example of railway transport, describe the directions of digitalisation of railway transport, which is a link between the branches of the national and partly global economy. The emphasise the advanced development of scientific and technological progress in the transport industry – the “Digital Railway” project, which generates related tasks, one of which is the modern training of engineering personnel and the consolidation of digital competencies and metaskills in professional standards.

Keywords: professional competencies, digital engineer competencies, digital railway, railway engineer, new professional standards.

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Introduction

The advanced countries of the world today are on the border of the fourth and fifth technological modes [Uskov, 2020], but they widely use electricity, which is typical for the third mode. Some countries, such as the US, Japan, EU countries, and some countries in Southeast Asia, have already moved into the fifth technological order and are even at the beginning of the sixth.

The fifth industrial technological order uses nuclear energy as the main resource and is associated with the development of electronics and microelectronics, information technology, industrial biotechnology, genetic manipulation, the development of automated technical systems, the transfer of information by various types of technologies, non-traditional energy sources, the industrial use of space, the emergence of space communications, etc.

The main trend in the digital economy of the world is technological progress based on advanced technologies: blockchain, Internet of Things, artificial intelligence, unmanned devices, digital twins, augmented reality, virtual reality, 3D printing and robotics. Currently and in the near future, specialists in the field of big data (Data Scientist), machine learning engineers (ML-engineer), developers in the field of artificial intelligence (AI-developer), UI researchers, IT specialists in the field of biomedicine, specialists in process automation, information security, software. It is expected that the pace of technology adoption will accelerate in some areas of the economy, so cloud computing, big data, digital twins, e-commerce are becoming the most in demand.

Structural changes in the modern economy have prompted in Russia a demand for professions in areas that are relevant under sanctions: logistics, analytics, agriculture, industrial production, transport, that is, primarily for engineering and technical workers. To integrate into the digital economy, Russian railways need to have not only physical infrastructure, but also digital skills for its operation by engineering and technical workers.

1. Research methodology

The aim of the study is to analyse the current requirements for the professional competencies of railway engineers, primarily for their digital literacy and ability to work with special software. In the article, the authors clarify the list of software systems that are included in the special digital competencies of a railway engineer.

The subject of the study is the composition of the digital competencies of a railway engineer. The object of the study was a set of modern competencies that a specialist needs to work on a digital railway.

The authors briefly describe the directions of digitalisation of rail transport, which is a link between the sectors of the national and partly the world economy. Emphasis is placed on the advanced development of scientific and technological progress in the transport industry - the Digital Railway project, which generates related tasks, one of which is modern training of engineering personnel and the consolidation of digital competencies and meta-skills in professional standards.

The hypothesis of this study is the message that the following set of competencies is important for a modern railway engineer working in a digital economy: soft, hard skills (with knowledge of special software) and meta-competences that generate new skills.

In the course of the study, the following scientific methods of cognition were used: literature analysis, synthesis, comparison, induction, systematisation and classification.

As part of the federal project "Assessment and development of managerial competencies in Russian educational organisations" in 2021, pursuant to the list of instructions of the President of the Russian Federation, 41 competence centers were created on the basis of leading research universities in 21 regions of Russia. The task of the centers is to be a link between university students, employers and the state authorities of the region. At the moment more than 70 thousand students are involved in the project, and this figure is increasing every day. It is planned that by 2023, about 300,000 students will undergo competency diagnostics[1]. In 2021, only 3% of students, having shown a high level of competencies, were tested in four tools and six competencies. For this reason, the question arises of revising job profiles that do not meet modern requirements and changing the learning process in educational institutions that should offer training in accordance with new digital trends [Parkhaev et al., 2021].

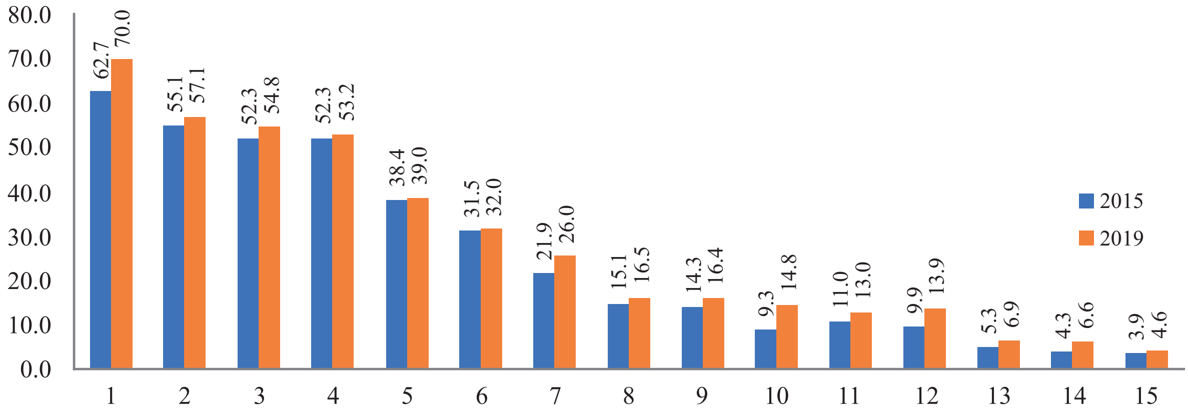
Research by the Higher School of Economics[2] and state statistics[3] on the use of specialised software that requires the staff of Russian institutions to have the appropriate skills and knowledge are shown in Fig. 1.

The data of Fig. 1 indicate a low level of use of special software compared to general computer programs for enterprise management.

The digital transformation of the railway implies the creation of innovative technical vehicles, traffic management, railway infrastructure, the creation of automated software systems for the implementation of the full cycle of business processes in rail transport, logistics, etc., to implement such a large-scale project of the country's digital economy, specially trained personnel with both a traditional set of competencies and digital industry-specific competencies. We believe that in carrying out the digital transformation of rail transport in Russia, it is extremely important to consider what is being done in Europe and China. To determine what employees are needed on a digital railway in Russia, it is necessary to understand according to what standards, technological solutions and based on what world experience this railway will be built. In this regard, it becomes important to continuously train personnel in new competencies. Online learning provides not only the opportunity to take professional training courses directly at the workplace, but also expands the network of experts and colleagues for information exchange. For example, The Engineering Institute of Technology (EIT) in Australia offers a two-year online study program to gain knowledge and skills in the latest rail technology[4]. An integral part of the distance course program is reflexivity and constant feedback, not only in terms of assessing acquired knowledge and skills, but also in terms of accompanying students with

[1] Project results for 2021. https://vk.com/@mephi_ccenter-itogi-proekta-za-2021.
[2] Information Society in the Russian Federation (2020): stat. Sat. M.: NRU HSE, 2020.
[3] Trends in the development of the information society in the Russian Federation (2020): brief stat. Sat. M.: NRU HSE, 2020.
[4] On track to becoming a railway engineer. https://www.eit.edu.au/on-track-to-becoming-a-railway-engineer/#Ancor.

Fig. 1. Share of enterprises using specialized software
(% of the total number of enterprises)



1 – Electronic document management systems
2 – Software for financial settlements in electronic form
3 – Software tools for solving organisational, managerial and economic problems
4 – Electronic legal reference systems
5 – Software for managing the procurement of goods (works, services)
6 – Software for providing access to databases via global information networks, including the Internet
7 – Software tools for product sales management
8 – Software for the management of automated production and / or individual technical means and technological processes
9 – Training programmes
10 – ERP-systems (enterprise resource management systems)
11 – Design software
12 – CRM-systems (customer relationship management)
13 – Editing and publishing systems
14 – SCM-systems (supply chain management)
15 – Scientific research software

Source: [Simarova et al., 2022].

information about events taking place in this area of study [Kamshilin et al., 2022].

2. Literature review

A feature of the theoretical premises on the issue of research is the fact of their novelty. The classification of technological structures is presented in the works of K. Schwab, an attempt to determine the contours of the new world order was made in the works of famous Russian scientists: D. Lvova, S. Glazyev, V. Kharitonova, V. Ivanova, V. Syretsky, A. Voronov and many others. A retrospective review of the digital economy development was carried out by A.N. Kozyrev.

The issues of economic development of cities with a multimodal transport system in the digital economy are disclosed in the articles by I. Bratishcheva, I. Sokolova, A. Misharina, V. Kupriyanovsky, O. Pokusaev. The problems of international logistics, where rail transportation is present, are raised by researchers O. Dunaev, A. Zazhigalkin, S. Yevtushenko and others.

The problems of economic partnership for the economic development of the EAEU countries were covered in the publications of S. Glazyev, A. Petrova, V. Kupriyanovsky, Yu. Kupriyanovskaya, I. Sokolova, A. Stepanenko and O. Pokusaev. From the point of view of technical means and technologies of cargo transportation, the works of S. Vinogradova, M. Mekhedov and A. Khomova.

In recent years, researchers I. Simarova, Yu. Alekseevicheva, D. Zhigin, V. Vasina, I. Chernenko, E. Sysoeva, A. Shevyakova, E. Petrenko and many others deal with the professional competencies of digital economy specialists, their role in the modern labor market, and the impact of digital skills on wage formation.

The role of human capital in the digital economy is fundamental, and foreign scientists and researchers paid attention to this fact: S. Carpitella, F. Carpitella, A. Certa, J. Benítez, J. Izquierdo, Sh. Guoa, J. Lia, J. Heb, W. Luoa, B. Chenc - and their Russian colleagues: E. Leven, A. Suslov, S. Dyatlov, M. Dobrokhotov, O. Roman.

With regard to railway transport, in particular in matters of higher education and continuous training of engineering and technical workers on the digital railway, one can note the works of A. Khabarov, V. Radchenko, A. Vylegzhanina, S. Tsybukova, N. Toivonen.

The methodology for integrating digital technologies into professional standards was described by O. Spiridonov, M. Shklyaruk, N. Garkusha.

To conduct this study, the authors used statistical data from world surveys, The Future of Jobs (2020) and others, analytical collections of the Higher School of Economics and other reference literature.

3. Research tools

The railway is a connecting network of the country's economy, therefore, the creation of a strong national capital that dominates all sectors of the digital economy, including the railway industry, can become one of the priority areas of national policy. The digital economy and rapid technological development put forward demands on the professional competencies of railway technicians. What modern professional competencies and personal qualities should technical specialists, primarily railway engineers, have in the 21st century?

Technologies such as 3D printing, remote sensing of the Earth, the Internet of Things, artificial intelligence, digital twins, avant-garde biotechnologies, nanomedicine, the digital footprint, the digital human shadow, as well as the development of modern vehicles and communications will require trained professionals with digital competencies. Workers with relevant information competencies, programmers and engineers will always be in demand in the digital economy, including on the digital railway.

Russian railways have already implemented information services that manage the train fleet, assess the technical condition of train sets, build a transportation plan in order to reduce wagon downtime and unproductive empty runs, plan optimal routes, increase the level of customer service, and make an instant calculation of the cost of transportation. The concept of digital twins, adopted by Russian Railways, is part of the fourth industrial revolution and is designed to improve the quality of products through predictive detection of possible problems and modeling of results. The concept defines four areas - static objects (the superstructure of the railway), dynamic (locomotives), processes (management) and parameters of the external environment (marketing and macroeconomic data)[5]. The digital twin is becoming an integral attribute of every transport enterprise due to large-scale digitalisation [Rimskaya, Anokhov, 2021].

The digital transformation strategy of Russian Railways until 2025[6] contains included projects for the development and implementation of digital technologies and platforms in the holding. The comprehensive innovative development program of the Russian Railways holding for 2016–2020 is considered a priority for the implementation of the Digital Railway project, the purpose of which is to significantly reduce operating costs and improve the safety and reliability of rolling stock.

The scientific and technical project "Digital Railway" is associated with the knowledge economy, knowledge management and knowledge technologies, which determines many features of the transformation of the industry, which entailed new requirements for the professional competence of railway industry workers [Khabarov, Volegzhanina, 2020]. The Digital Railways project will significantly change the composition of positions, the content of the activities of the employees employed in it and the methods of work, requiring new competencies.

Rail transport, like other modes of transport, is changing significantly under the influence of digital transformation. Global trends are associated with the unification of signaling and control systems, the digitalisation of rolling stock, modernisation, traffic management and train automation. An important advantage of digitalisation should be noted - the possibility of increasing throughput without increasing the physical infrastructure. Constant monitoring of railway loading and identification of bottlenecks allows you to reorganise processes to make the most efficient use of physical facilities.

The Digital Railway project was initiated as part of the implementation of the Development Strategy of the Russian Railways holding for the period up to 2030, approved by the Board of Directors of Russian Railways on December 23, 2013. One of the main objectives of the project can be declared to improve the quality of logistics and transport services provided using digital technologies, and the fundamental goals are:

1) creation of a single information space for freight traffic;
2) creation of a single information space for passenger traffic;
3) formation of end-to-end digital technologies for organizing the transportation process;
4) creation of a unified integrated automated management system to increase the efficiency of corporate governance and the social sphere.

According to this project, it is planned to create at least eight platforms, and each will become the basic element of the IT infrastructure for the key areas of activity of Russian Railways: e-commerce, intermodal freight and multimodal passenger transportation, management of the transportation process and traction rolling stock, organisation of transport and logistics nodes and interaction of linear infrastructure operators[7].

The implementation of the Digital Railway project is carried out using the tools available at Russian Railways: an informatisation program, investment projects, a plan for scientific and technological development and the creation of new software systems. Today, the digital railway consists of key subprojects:

1. "Digital rails" are used by the railway infrastructure and provide the movement of freight and passenger

[5] Russian Railways wants to create "digital twins" of technological processes for the modernization of stations. https://company.rzd.ru/ru/9401/page/78314?id=190657.
[6] Russian Railways Digital Transformation Strategy. https://www.tadviser.ru/index.php.
[7] Id.

trains. IT systems are actively used to work out routes and schedules for trains throughout the network, set the interval for the operation of arrows and traffic lights. They also allow you to make the necessary changes quickly[8].

2. "Digital Wagon"[9], or "Smart Wagon", is a project developed by JSC VNIIZHT and allows to build predictive analytics based on data on the state of wheel sets. Work on the digital twin of a freight car requires synergy from all participants in the transportation process.
3. "Digital railway station"[10] - a project to create an energy-efficient railway station is being developed at JSC NIIAS. The creation of this project requires the use of an interdisciplinary approach and is a complex of interrelated technical means and devices that provide the calculation and execution of technological operations with minimal human participation.
4. In the field of freight transportation, it is planned to create an integrated CRM system for interacting with customers, introduce smart contracts on a blockchain platform, and develop an electronic trading platform[11]. The CRM system contains information about about 300 different products and services of the Russian Railways holding and its subsidiaries.
5. Based on the analysis of world experience and trends in its development, Russian Railways determines the range for regular piggyback trains. The technology of transportation using piggybackers is developing towards making them mobile: they are equipped with wheels, and in the future they can be equipped with an autopilot capable of independently building a route and moving short distances without human intervention.
6. Currently, it is proposed to use navigation seals, that is, seals equipped with navigation devices (trackers)[12]. Electronic seals[13] for wagons operate on the basis of the GLONASS navigation system. The technology was launched in 2021 and helps in tracking the transportation of goods by controlling the location of wagons, the integrity of the cargo and the route of the train.
7. Another development in the field of unmanned technology is the “machine vision” complex. The device can detect any obstacle on the railway track and signal it to the dispatcher. This technology makes it possible to introduce a new specialty - the driver-operator, who is able to control several locomotives from the office.
8. Russia can enter the top three countries producing trains with a speed of 400 km/h. Now the task is to create a high-speed digital train by 2028, which will have a digital filling.

Developments related to unmanned trains began in 2015, and now unmanned trains are a reality. At the Experimental Ring of JSC VNIIZhT, the largest test site in the country, in 2022, the unmanned Lastochka, an intellectual product of JSC NIIAS, successfully passed the test complex. In the medium term, unmanned cargo trains can also be expected.

When working in a digital environment, the security of information transmission is important, so the development of quantum communication technologies has been launched in parallel. If we consider long distances, then the most secure technology for transmitting information and messages are quantum technologies. The importance of interoperability for the digital transformation of railway transport is beginning to be discussed in the professional community [Rozenberg et al., 2021].

The main issue of the competitiveness of companies that operate in the transportation market and are interested in increasing the income of commodity producers, developing non-commodity exports and increasing the volume of movement of goods is the digitalisation of the transport and logistics industry. To achieve this goal, the Strategy for the Digital Transformation of the Transport Industry of the Russian Federation until 2030 was adopted, the main directions of transport development of which are:

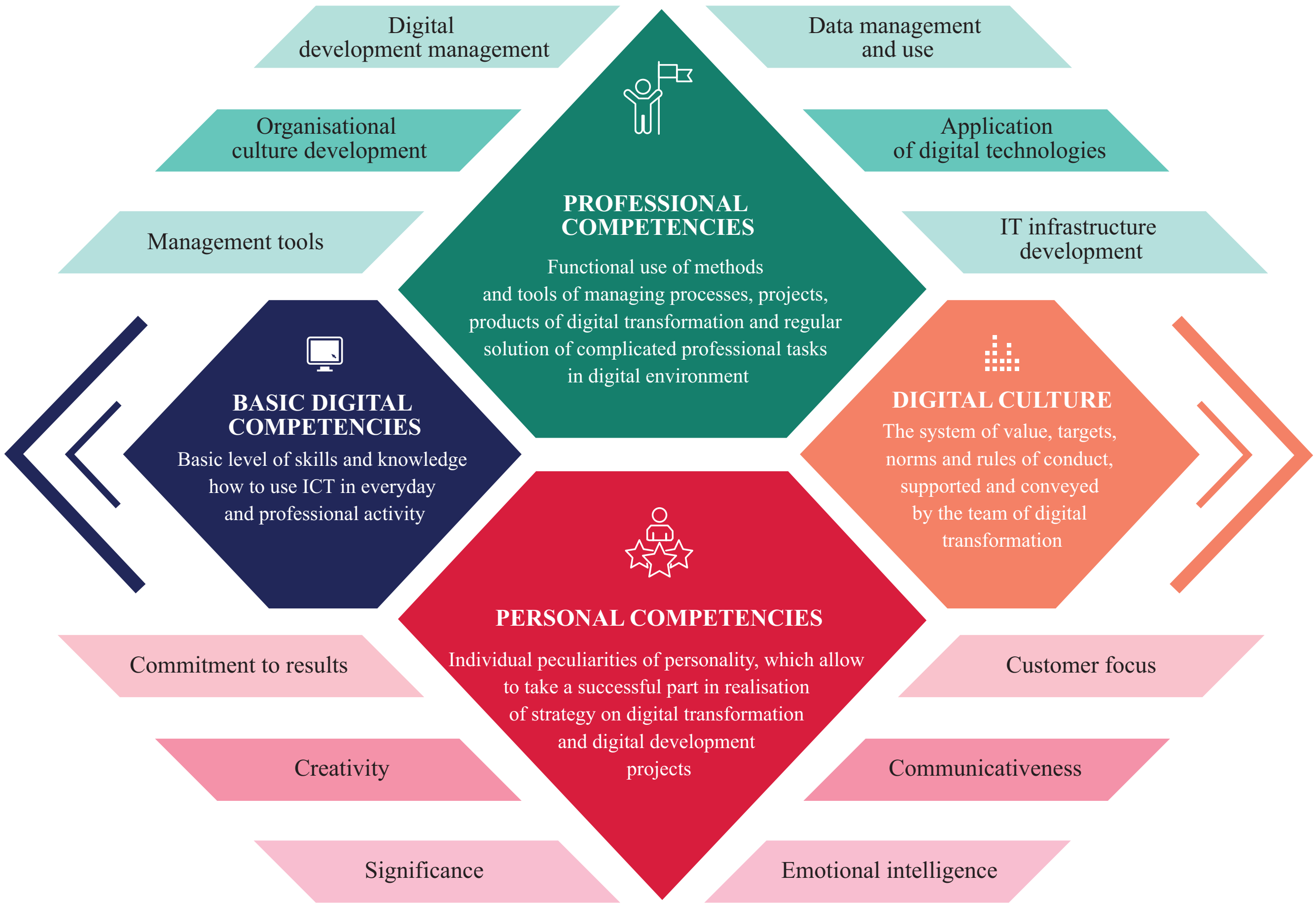
- digital control of the transport system of the Russian Federation;
- digital twins of transport infrastructure facilities;
- drones for passengers and cargo;
- seamless cargo logistics;
- green digital passenger corridor;
- digitalisation for transport security.

The transport industry, which provides the opportunity for the interaction of all types of transport and is the life support link of the digital economy, is already in dire need of qualified engineering personnel. To prepare them, the transport education system needs modernisation[14], so that by 2024 all graduates of transport universities will have the necessary digital competencies. It is obvious that universities cannot cope with the task on their own; close cooperation is needed with specialised companies and research institutes that have modern testing and laboratory facilities and use digital tools in practice.

Some universities quickly responded to the requirements for specialists in the digital economy. Thus, the Higher School of Economics has developed a procedure for conducting independent examinations in digital competencies, which are built into the Regulations on the organisation of intermediate

[8] Digital or railway? What to expect in the future? https://vc.ru/transport/215389-cifrovaya-ili-zheleznaya-doroga-chto-zhdat-v-budushchem.
[9] JSC VNIIZhT passed tests of the Digital Freight Car system. https://itsjournal.ru/news/v-ao-vniizht-proshli-ispytaniya-sistemy-tsifrovoy-gruzovoy-vagon/.
[10] JSC NIIAS is working on the digital transformation of railways. https://nvdaily.ru/info/176913.html.
[11] Russian Railways considers the program of "digital transformation" up to 2025 to pay off. https://company.rzd.ru/ru/9401/page/78314?id=182738.
[12] Electronic sealing: new concepts and reality. https://www.rzd-partner.ru/zhd-transport/comments/elektronnoe-plombirovanie-novye-ponyatiya-i-realnost/.
[13] Electronic navigation seals GLONASS. https://gpscool.ru/sistemy-gps-slezheniya/elektronnye-navigatsionnye-plomby-glonass.
[14] Digital competencies. https://company.rzd.ru/ru/9401/page/78314?id=145125.

Fig. 2. The structure of the competency model



Source: Competence Model of the Digital Transformation Team in the Public Administration System. https://hr.cdto.ranepa.ru/model-kompetencij-komandy-cifrovoj-transformacii.

certification and ongoing monitoring of students' progress at the Higher School of Economics[15].

Specialists of the Center for Training Leaders and Digital Transformation Teams of the RANEPA have developed a methodology for assessing the competencies of participants in digital transformation. The general structure of the competency model is shown in Fig. 2. The competency model correlates with the new professional standards of the Ministry of Labor for Transport.

A new concept of "meta-competencies" (metaskills) has appeared, which is understood as "competencies that allow the formation of new knowledge and competencies" [Mikhailichenko et al., 2016]. The main meta-competences form the foundation for the qualitative growth of an employee at the organisational, social and personal levels. A person will be able to develop other competencies faster and achieve results by owning metaskills.

In Russia, there is a need to develop unified professional standards that will allow linking and adjusting existing educational standards to the necessary qualification requirements, taking into account digital competencies.

Digital competencies, which are currently needed by employees of modern production, are understood as knowledge of communication and digital technologies, as well as a set of skills, knowledge and skills in algorithmic thinking, programming and data analysis. In a broad sense, digital competencies can be called the use of digital technologies in professional activities, training and social communications [Vuorikari et al., 2016], which will ultimately affect the economic development of the country.

Work in this direction is carried out by an advisory body - the National Council for Professional Qualifications under the President of the Russian Federation. Digital competency levels have been defined and professional standards are being prepared for publication[16]:

1. Information and data management.
2. Conscious acquisition of skills or self-development in the face of uncertainty.

[15] The procedure for organising and conducting independent examinations on digital competencies. https://www.hse.ru/dataculture/exams.

[16] Minutes of the NSPK dated June 25, 2020 No. 45. https://nspkrf.ru/documents/materialy-natsionalnogo-soveta/2020-ns/2296-45-25062020/file.html.

3. The ability of a person to build a logical conclusion, evaluate and credibility of information or critical thinking in a digital environment.
4. The process of information transfer and communication or communication and cooperation in the digital environment.
5. The ability to create something new or creative thinking.

Four levels of competencies were selected for employees and workers according to the level of complexity and type of tasks[17] to be solved:

1. Competencies for working with computers, skills and knowledge necessary to view textual and graphic information or basic.
2. Competencies for working with universal text and graphic editors and global networks or universal.
3. Competencies to work with programs for computer-aided design, programs for the development of technological documentation, programs for the finite element method or general professional.
4. Competencies that are in demand by a narrow range of specialties of workers and professions or professional ones.

It is assumed that a significant part of the digital core competencies in professional standards will remain, since the training of engineers for railways is impossible without knowledge about the means of transportation and railway infrastructure. At the same time, there will be fundamentally new requirements for the level of training of engineers - digital competencies necessary for intelligent traffic control and digital railway infrastructure.

To acquire modern digital competencies of railway transport employees, a multimedia communication platform was created on the basis of the Sochi branch of the Sirius Center to integrate new research practices and methods for developing digital products into corporate development programs of companies[18]. The prerequisites for the creation of the center were the lack of digital transformation leaders and teams, as well as employees with advanced competencies for working with data, digital technologies and devices, software, including with colleagues (soft skills).

The set of competencies that an employee should possess depending on their role is traditionally divided into two groups: soft skills and hard skills. Soft skills, or soft skills, are super-professional, universal skills that are not important for a particular job, but without them it is impossible to achieve success. These personal qualities and skills of an engineer include: critical thinking, creativity, persuasiveness, self-motivation, responsibility, time management, adapting to changes in the work environment, the ability to build communications, emotional intelligence. Hard skills, or professional skills, are technical abilities and skills that can be measured and that can be obtained in the learning process. They are often associated with a specific profession: working with technology, programming, working with equipment, knowledge of special industry software, etc.

For example, leadership and communication are interpersonal skills that help engineers be more successful because they complement their job skills. As a rule, the right hemisphere of the brain is involved in the formation of soft skills, and the left hemisphere is involved in the formation of hard skills.

According to the results of a survey on the website of the Russian Railways Digital Competence Center[19] 42% of respondents noted the importance of combining hard skills and soft skills. 25% of survey participants voted for the development of soft skills, believing that it is impossible to build a successful career without soft skills; 14% of the votes were given for the development of hard professional competencies. It should be noted that in different companies the list of soft and hard skills may differ, as well as their interpretation by recruiters.

The Ministry of Labor of the Russian Federation responded to the request of employers in the transport industry and developed a number of professional standards for railway specialists in 2022:

1. Engineer for the operation of technical means of railway transport.
2. Specialist in the operational and dispatching management of railway transportation.
3. An employee for the maintenance and repair of railway traction and transformer substations, linear devices of the traction power supply system.
4. An employee for fencing work sites and securing rolling stock on railway transport.
5. Specialist in organising the work of the railway station and ensuring traffic safety.
6. Specialist in operational management of ensuring the issuance of traction rolling stock for trains, locomotive crews for work.

For example, in professional standard 17.063 "Engineer for the operation of technical equipment of railway transport" in the list of labor actions of an engineer it is prescribed:

1. Registration of documentation in an automated system using application software.
2. Accounting for technological violations and monitoring of failures of technical means using integrated automated systems.

Among the necessary skills of an engineer are mentioned:

1. Ability to use application software in the process of repair and maintenance of technical devices of railway transport.
2. Ability to work with electronic databases and information and analytical systems.

And among the necessary knowledge to perform a labor function, an engineer will need knowledge of a professional

[17] Spiridonov O.A. (2020). Accounting for digital technologies in professional standards. https://profstandart.rosmintrud.ru/upload/medialibrary/ff9/12.11.2020.pdf.
[18] http://cckrzd.ru/.
[19] Digital Competence Center of Russian Railways. https://cckrzd.ru/questions.

Table 1
Automated systems of “Russian Railways” JSC

№	ACS	Name
1	PC GIP JSC Russian Railways	Geographic information platform JSC Russian Railways
2	АСУ ПРИГ	Automated control system for the motor-carriage complex of Russian Railways
3	АСУ НБД – 2 (СВПС)	Rolling Stock Interaction System
4	ПМ ЭТСО	Driver's electronic route
5	"Topomatic Robur - Railways"	The software package is intended for use in railway design and construction organisations
6	AS ETRAN	Platform for issuing railway documents for cargo transportation
7	АКС ФТО	Complex for sales blog - branded transport service systems
8	АС АПВО	System for analysing the planning and execution of "possessions"
9	АС БНУиО	Automated system of accounting and tax accounting and reporting
10	AS OTD	Automated system of operational and technical documentation
11	АСДК	Automated supervisory control system
12	АСНТИ	Automated research and development information system
13	АСОВ	Automated system for organising car traffic
14	ATCS	Automated Tariff Control System
15	АСУ ВОП	Automated management system for issuing and canceling warnings
16	ACS S	Shipper's automated control system
17	ACS “Freight Express”	Automated control system "Freight Express"
18	ACS RT	Automated railway transport control system
19	ACS SS	Automated control system for marshalling yard
20	ACS SSP	Automated control system for shift-daily planning of cargo work
21	ACSST	Automated control system of the railway station
22	ACST-T	Controlling regional information and signal system of the locomotive economy
23	APCS	Automated process control system
24	ACS E	Automated management system for the economy of electrification and power supply and many other complexes

Source: compiled by the authors.

standard for organizing the technical operation and repair of technical equipment of railway transport.

The content of all the above standards mentions the requirement to own special software, the ability to work with analytical automated systems, databases. Thus, the use of industry software is part of the special digital competencies of an engineering worker, which are enshrined in professional standards.

In the foreseeable future, digitalisation will affect all technological processes on the railway without exception. Among the software complexes of Russian Railways, developed at research institutes and specialized companies and implemented in production activities, one can list a lot of software for special industry purposes.

The leading scientific institute of the industry - the Research Institute of Railway Transport (JSC VNIIZhT) has developed and put into operation several well-known software systems on the railway:

- ACS "Express" - a new generation is a system for managing passenger traffic, the prototype of which began work half a century ago;
- "Elbrus M" - predictive macro model of train traffic;
- "SADKO" - system for monitoring the work of special rolling stock "SADKO";

- subsystem "PAUK" - a subsystem of acoustic ultrasonic control of the undercarriage of the rolling stock;
- system of prescriptive diagnostics of an electric train;
- automatic train guidance system;
- technology of accelerated cargo transportation;
- guide "Ural-VNIIZhT" - a program for automating the management of operational work.

JSC VNIIZhT also develops educational solutions. In 2021, a new interactive full-format educational program "Transport Logistics" was announced, presented in two versions: advanced training (96 hours) and professional retraining (256 and 512 hours). The program has received recognition among participants in the transportation market.

According to the General Director of JSC "VNIIZhT" S.A. Vinogradov[20], today the institute has many different projects in the field of infrastructure development, transportation process technologies, digitalisation and transformation programs using modern IT technologies. The Institute takes an active part in at least 14 major technological and digital development projects of Russian Railways.

Award-winning software solutions from another major scientific institute of the railway industry - JSC NIIAS[21]:

- system of technical and commercial control of the state of trains;
- system of interval regulation of train traffic;
- a way to control the technological process of a railway station.

Some of the software solutions used on the railway, which are the foundation for the digital competencies of a railway engineer, are listed in Table 1.

To improve the management of the production activities of Russian Railways on the railways, as part of the development of the digital environment, it is planned to create completely new car and train models, as well as a sales module for the branded transport service system. As noted in the article [Anokhov, Rimskaya, 2021], "digitised routine processes will automatically cease to be a source of profit and the basis of competitiveness."

In the ACS of Russian Railways today there are about a thousand subtasks and applications[22], that operate in the areas of the holding's activities. The automated system integrates the following subtasks:

1) transportation process management, including the transportation process model;
2) marketing and organisation of freight and passenger transportation, including the system of centralised preparation and execution of transportation documents;
3) corporate infrastructure;
4) rolling stock, including an automated data bank of freight cars;
5) economics and budgeting;
6) investment activity and finance;
7) strategic development;
8) investment activity and security in the field of information technology.

Among the professions of the future on the digital railway[23] one can already name those based on the digital competencies of an engineer:

- operator of unmanned transport systems;
- engineer of artificial intelligence and machine vision systems;
- specialist in cybersecurity of railway transport control systems;
- specialist in the modernisation of the transport system;
- architect of intelligent control systems;
- designer of digital commercial services..

The development of the digital economy is a strategic task that cannot be solved without the availability of digital competencies among workers in various sectors of the economy, primarily high-tech ones. The final results of the implementation of the federal project "Personnel for the Digital Economy" is the achievement by 2024 of the planned performance indicators, in particular, 120 thousand university graduates per year in areas related to information and communication technologies, and 800 thousand university and college graduates per year with digital competencies[24].

Following the Strategy for the Development of the National Qualifications System until 2030, priority areas for the development of the qualifications system until 2024 were identified, in which the emphasis is on harmonising the procedures for the state final certification of a university graduate with an independent assessment of his qualifications, creating conditions for confirming the results of self-education using the qualification assessment procedure , as well as expanding its use in industrial enterprises.

Conclusion

In the era of the rapid development of digitalisation, it is necessary to restructure the system of internal corporate training in terms of the development of digital competencies in connection with the development of informatisation. This process should be implemented starting from the very first stage of training future specialists and continuing continuously throughout their careers.

For the foreseeable future, engineering professions will need the following qualities:

- attention to detail;
- flexibility and stress resistance;
- critical thinking;
- initiative;
- ability to negotiate;

[20] Breakthrough results on the horizon of 5-10 years. Interview with S.A. Vinogradov to the newspaper "Gudok". https://gudok.ru/content/first_person/1611677/.
[21] NIIAS presented new traffic control technologies. http://niias.ru/news/smi/niias-predstavili-novye-tekhnologii-upravleniya-dvizheniem/.
[22] Informatisation in railway transport. History and modernity. https://company.rzd.ru/ru/9401/page/78314?id=22800.
[23] Professions of the future. https://cckrzd.ru/professions_of_the_future.
[24] Personnel for the digital economy. https://data-economy.ru/education.

- possession of information technologies and special software for performing specific activities;
- creativity.

Undoubtedly, leadership qualities and emotional intelligence will remain among the important competencies. Skills related to innovative technologies will become more in demand: quick learner, analytical thinking and deep immersion in a specific area.

All of these skills are the basis, a kind of superstructure that is necessary for the development and formation of new competencies (metaskills).

Scientists from the Carnegie Institution for Science conducted research and made conclusions that proved that people with emotional intelligence, networking and leadership qualities have an 85% chance to achieve financial success, and people with only technical knowledge, - no more than 15%[25].

What kind of meta-competences does a modern engineer of a high-tech industry need in a digital economy? Among the meta-skills[26] that are not currently taught in a university, school or college are: mentoring and mentoring, critical thinking, communication, project management competencies, problem solving and emotional intelligence.

In order for our country to take a leading position in the global economy, ensure economic security and preserve its national borders, it is necessary to continue development in the development of new, non-traditional energy sources, follow the scenario of advanced technical modernisation, raise the level of training of specialists involved in the digital economy, in particular in the digital railroad.

References

Anokhov I.V., Rimskaya O.N. (2021). The impact of digitalization on industry risks (exemplified by transport). *Strategic Decisions and Risk Management,* 12(3): 212-219. DOI: 10.17747/2618-947X-2021-3-212-219. (In Russ.)

Kamshilin N.I., Khomova N.A., Sorokina N.M. (2022). Adaptation of specialists of the organisation of transportation and management in transport to changes in logistic market through the professional learning environment of distance education. In: *Railway: The Way to the Future:* source book of the I International Scientific Conference for Postgraduates and Young Scientists. Moscow, 219-227. (In Russ.)

Mikhailichenko S.A., Buryak Yu.Yu., Afanaskova Yu.A. (2016). Metacompetencies as the basis for successful self-realization of graduates in the labor market. In: *Assistance to the professional personality development and young specialists employment in modern conditions.* Belgorod, Belgorod State Technological University named after V.G. Shukhov, 94-101. (In Russ.)

Parkhaev A.A., Mekhedov M.I., Khomov A.V., Anokhov I.V. (2021). Personnel training in digital logistics and supply chain management. *VNIIZHT Scientific Journal,* 80(5): 285-292. DOI: https://dx.doi.org/10.21780/2223-9731-2021-80-5-285-292. (In Russ.)

Rimskaya O.N., Anokhov I.V. (2021). Digital twins and their appliance in transport economics. *Strategic Decisions and Risk Management,* 12(2): 127-137. DOI: 10.17747/2618-947X-2021-2-127-137. (In Russ.)

Rosenberg I.N., Dulin S.K., Dulina N.G. (2021). The importance of interoperability for the digital transformation of rail transport. *Railway Science and Technology,* 2: 3-12. (In Russ.)

Simarova I.S., Alekseevicheva Yu.V., Zhigin D.V. (2022). Digital competencies: concept, types, assessment and development. *Russian Journal of Innovation Economics,* 12(2): 935-948. DOI: 10.18334/vinec.12.2.114823. (In Russ.)

Uskov V.S. (2020). Scientific and technological development of the russian economy in the transition to a new technological order. *Economic and Social Changes: Facts, Trends, Forecast,* 13(1): 70-86. DOI: 10.15838/esc.2020.1.67.4. (In Russ.)

Khabarov V. I., Volegzhanina I. S. (2020). Digital railway as a precondition for industry, science and education interaction by knowledge management. *IOP Conference Series: Materials Science and Engineering,* VIII International Scientific Conference Transport of Siberia - 22-27 May 2020, Novosibirsk, Russia. https://doi.org/10.1088/1757-899X/918/1/0121892.

Vuorikari R., Punie Y., Carretero Gomez S., Van Den Brande G. (2016). *DigComp 2.0: The digital competence framework for citizens. Update phase 1: The conceptual reference model.* EUR 27948 EN. Luxembourg, Publications Office of the European Union.

[25] Soft skills are 85% of success in the profession. How to pump them up - tips from Harvard (2020). https://zen.yandex.ru/media/rbc_trends/soft-skills--85-uspeha-v-professii-kak-ih-prokachat--sovety-iz-garvarda-5e95c8a6469c497210cff9ac.

[26] Bogina K. (2021). How can companies develop the meta-competencies of employees. https://theoryandpractice.ru/posts/19408-kak-kompaniyam-razvivat-metakompetentsii-sotrudnikov.

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Strategy of digital transformation of industrial enterprises: The effects of the introduction of smart manufacturing technologies

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Abstract

The socio-economic effects from the introduction of smart manufacturing technologies are of significant interest in terms of their generalisation and systematisation at the current stage of the digital transformation on industrial enterprises, as well as the objectives in the context of industrial modernization and new business model development. The proposed systematisation is based on the allocation of three groups of socio-economic effects according to the main direction of their action. The first group of effects primarily leads to reduction in the costs of industrial enterprises. The second group of effects leads mainly to an increase in revenues: some effects to a greater extent in the short and medium term, others in the long term, including through the creation of long-term distinctive capabilities, unique competencies, and sustainable competitive advantages for industrial companies. The third group of effects includes social and economic effects that are broader in focus and have a multiplicative effect, as well as the character of positive externalities (external effects).

As a result of systematisation, the author identified in three groups, respectively, 12, 8 and 13 effects from the implementation of the complex of smart manufacturing technologies. The author stresses the particular importance of studying the socio-economic effects from the implementation of smart manufacturing technologies, since many improvements at the intersection of production and social transformation are currently insufficiently studied. It contrasts to the core production effects, many of which have been studied in sufficient detail by the scientific and expert communities. Systematisation, classification, differentiation and quantitative assessment of various socio-economic effects of the complex of smart manufacturing technologies can and even in a certain sense should (in the context of the tasks to modernise the economy and industries of the Russian Federation) become a separate subject area at the intersection of performance management and smart production.

Keywords: smart manufacturing, industrial enterprises, industry, digital technology, digital economy, digital transformation, Industry 4.0, cyber-physical system, business models, digital twins.

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Introduction

The smart manufacturing system has become one of the most significant technology complexes within the framework of the general trend of the formation and development of the digital economy. As defined by the US National Institute of Standards and Technology (NIST), Smart Manufacturing is "fully integrated enterprise manufacturing systems that are able to respond in real time to changing production conditions, supply chain requirements, and meet customer needs" [Merzlikina, 2021]. The concept of "smart manufacturing" can also be defined as the intelligent management and optimisation of business, production and digital processes along the entire value chain in real time [Geerts, 2016]. In another definition, the focus is on the potential for increased productivity: smart manufacturing is a combination of big data processing technologies, artificial intelligence and advanced robotics, interconnected machines and tools used to increase enterprise productivity and optimise energy and workforce [Phuyal et al., 2020a]. The complex of smart manufacturing technologies in the most extensive and enumerative interpretation combines digital product design, analytics, production process, inventory and supply chain system, product customisation, real-time operational process blocks, product delivery system and end customers using cloud computing, which allow to increase production to order and make product customisation and the overall maintenance of the supply and demand ecosystem more efficient [Phuyal et al., 2020b].

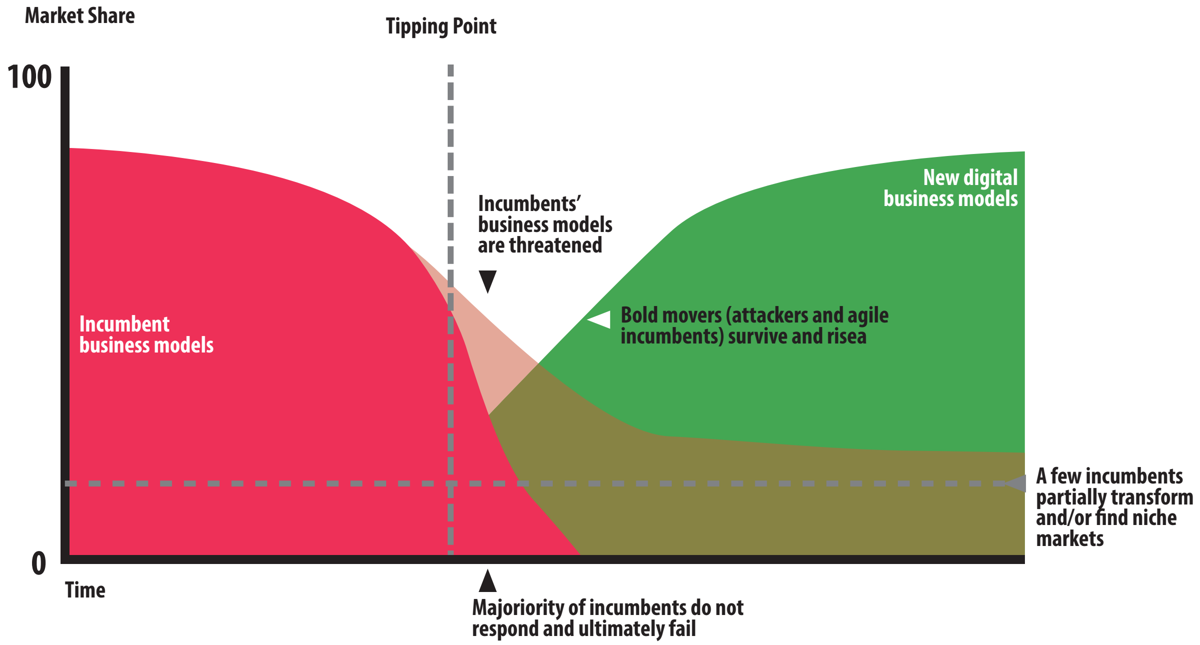
A very similar concept (which, in the context of this study, it is advisable to use as a full analogue for the term "smart production") "smart factory" refers to a factory that has reached a level that makes possible the functions of self-organisation in production and in all processes associated with it. The main advantage lies in the mutual complementarity of diversified areas of the production ecosystem, from smart production to smart logistics networks [Strozzi et al., 2017]. Powerful capabilities allow you to perform operations with minimal manual intervention and high reliability in various aspects of the ecosystem, including high values of automated workflows, asset synchronisation, improved tracking and scheduling, optimised energy consumption inherent in a smart factory to increase productivity, uptime and quality. The key capabilities of a smart factory are highly interconnected, transparent, proactive and flexible. This helps in the overall efficiency of the ecosystem supply chain [Odważny et al., 2018].

At the same time, there is a point of view that it is more expedient to consider two sets of technologies - "digital design" and "customised product" as separate components of the development of digital transformation of industrial enterprises beyond the scope of smart production in a narrower sense. The isolation of these two sets of technologies is justified primarily by autonomy (both software and process and organisational), as well as the distinctive features of their implementation and the specifics of the technology commercialisation logic, as well as those specific effects that were identified separately for customisation in the context of the digital transformation of industrial enterprises [Titov, Titova, 2022]. Based on these considerations, in this paper preference is given to a narrower definition of smart production, since it also seems appropriate from the point of view of describing and systematising the entire set of socio-economic effects from the introduction of a set of smart production technologies. A narrower interpretation of smart manufacturing allows us to more accurately define and delineate its effects in the context of the digital transformation of industrial enterprises.

It is also very important to understand the relationship between different sets of technologies and the choice of specific, niche business models by industrial enterprises. So, a monograph edited by A. Trachuk "Transformation of industry in the context of the fourth industrial revolution" presents three distinctive business models: a smart automated plant, a customer-oriented plant, a mobile plant [Trachuk et al., 2018]. It is logical to assume that industrial enterprises focused on the implementation of a set of "smart production" technologies will gravitate towards the "smart automated plant" business model. The success of the business of an industrial enterprise fundamentally depends on the degree of complementarity of the complex of digital technologies and the business model, since inconsistencies will affect the stability and effectiveness of both individual blocks of business processes and the entire strategy.

In industry, value creation processes are changing as information and communication technologies are integrated with manufacturing processes. This change could lead to efficiency gains and new business models. The digital disruption embodied in smart manufacturing is already here and happening faster than many companies thought. Numerous studies have shown that the use of intelligent manufacturing technologies provides the first mover advantage. For example, mid-sized companies that are more digitally advanced grow significantly faster than lagging companies. Producers can get ahead of the curve, capitalise on new opportunities. Studies also show that the relationship between investments in smart manufacturing technologies and the fourth industrial revolution, the results of innovation and productivity growth are non-linear and have a stable positive relationship only after a certain critical mass of investments has been reached [Trachuk, Linder, 2020]. Most companies that do not adapt their business models to the opportunities created by digital technologies will fail

Fig. 1. New digital business models are replacing old ones



Source: [Bughin et al., 2018].

[Bughin et al., 2018]. Figure 1 shows a tipping point where there is a sharp decline in the market share of traditional companies that have failed to respond to the challenges of the digital economy. This is partly due to an insufficiently structured understanding by companies of how to relate digital transformation tasks to the transformation of business models [Schallmo et al., 2018]. However, some companies manage to adapt primarily due to the rapid reorientation to niche markets.

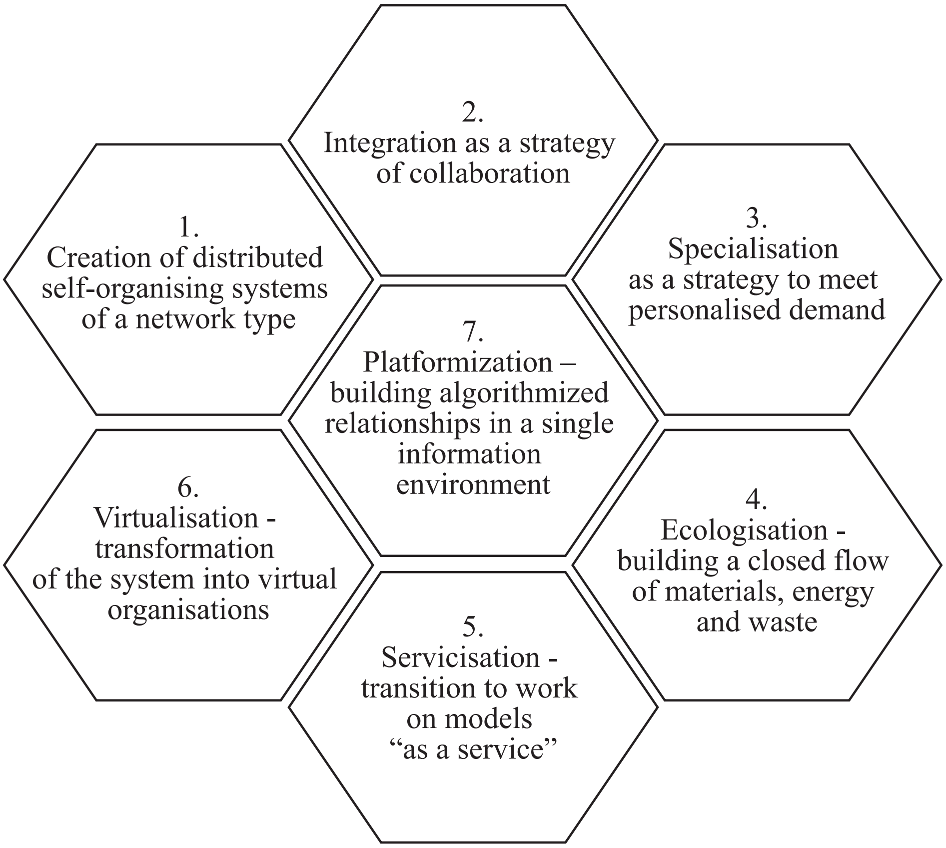
The intensive development of production systems based on the implementation of the Smart Production Complex of Technologies at the current stage is mainly carried out by innovative companies, as is supposed to be a model of Rogers's innovation: innovators (2.5%), the first users (13.5%), early majority (13.5%), late majority (34%), conservatives (16%). Of course, the model of diffusion of innovation is more emphasised by the user aspects from the consumer, and not organisational and informational. Nevertheless, according to the sum of the shares of innovators and early users (16%), this model can be relatively accurately, although in a general sense characterise the current stage of the use of smart production technologies in Russian industry. This

Table 1
Use of digital technologies in organizations by type of economic activity in 2020 (% of the total number of organizations)

Undustry	Cloud services	Big Data	Digital platforms	IoT	AI	Robots
Mineral extraction	19.0	21.8	13.2	14.6	2.5	4.2
Manufacturing industry	27.1	26.5	16.0	15.8	3.6	17.2
Energy supply	19.4	23.7	16.6	15.9	3.3	2.0

Source: compiled by the author based on [Digital economy.., 2022].

Fig. 2. Trends in the development of production and logistics systems



Source: [Myasnikova, 2020].

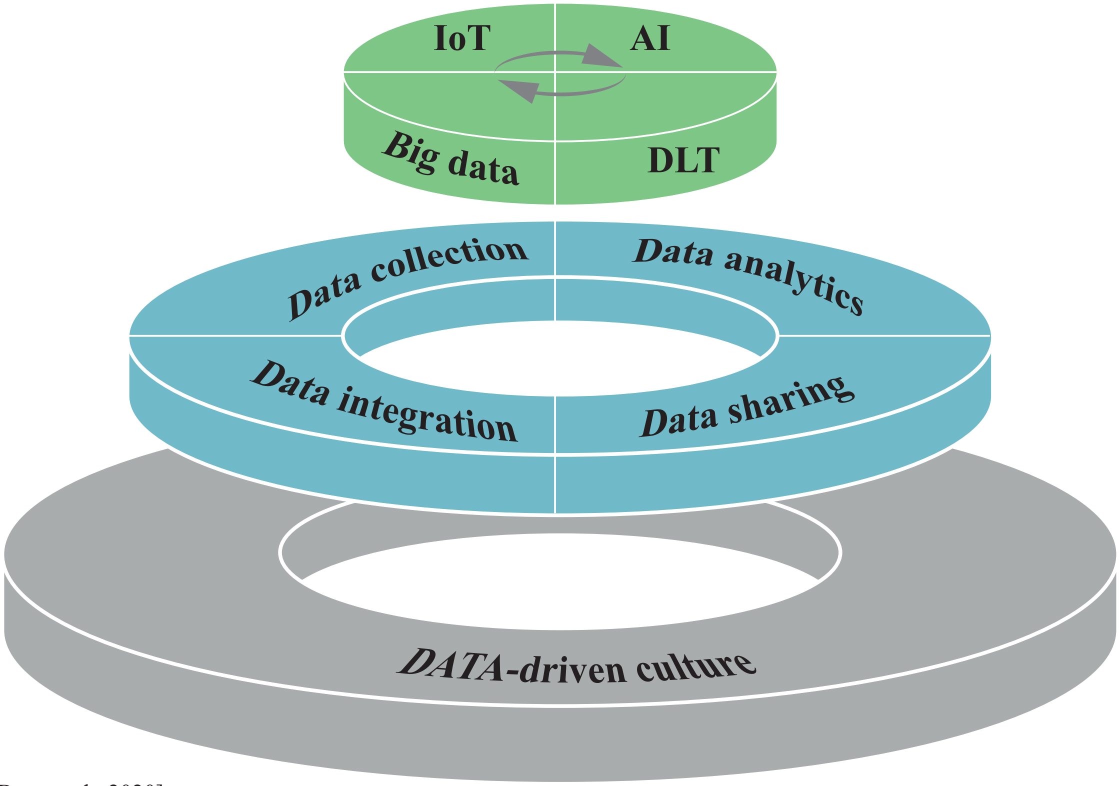
is quite well correlated with the data of the study "Digital Economy 2022", presented in Table. 1 In the context of the use of digital technologies in organisations according to the type of economic activity [Digital economy .., 2022]. Particular importance and interest now are the speed and completeness of the exit to the areas of the early and late majority of Rogers curve. At the same time, the studies noted that the development directions of Russian industrial companies correspond to global trends, however, the pace of implementation of digital initiatives is noticeably lag behind the pace of leading countries - according to various estimates, from 5 to 10 years [Digital transformation of industries .., 2021]. This explains the severity and urgency of modernisation tasks facing Russian industrial enterprises.

The concept of smart production is based on a whole range of advanced and promising technologies of the fourth industrial revolution (industry 4.0), among which, first of all, virtual modeling, big data, cloud computing, artificial intelligence (AI), Internet of things (IoT), connected robotics, predictive analytics, additive manufacturing, etc. [Digital transformation of industries.., 2021]. The diversity of a large conglomerate of smart manufacturing technologies to a large extent predetermines the variety of socio-economic effects from their implementation.

The generalisation of the main trends in the development of production and logistics systems based on the introduction of smart production technologies, proposed by O. Myasnikova (Fig. 2) is a bright example.

However, it is important to note that the pace of digitalisation depends not only on the development of technologies themselves. L. Berg and colleagues pay attention to the aspect of cultural and social transformation, speaking about the pyramidal structure of the digital economy (Fig. 3), where the fundamental layer is a data-based culture, or data-driven culture, which is understood as a culture of willingness to create and share data throughout the value chain [Berg et al., 2020].

Fig. 3. Structural representation of the digital economy



Source: [Berg et al., 2020].

1. Three groups of effects from introducing a complex of smart production technologies

The overall socio-economic effect from the introduction of a complex of smart production technologies in industry and in the economy as a whole is characterised by a large and rather diverse set of effects leading to an increase in the efficiency of enterprises, a reduction in many cost groups and an increase in demand for products and revenue, which ultimately affects growth of profitability. The scientific and expert communities have already developed a fairly mature and evidence-based understanding of a number of central effects of smart manufacturing. At the same time, a number of specific and broader socio-economic effects are still receiving insufficient attention even in the leading publications on the digital transformation of industrial enterprises.

Among the socio-economic effects of a complex of smart production technologies, it seems most appropriate to single out three enlarged groups of effects. The first on the main vector of action leads to cost reduction. The second leads mainly to an increase in revenue: some effects to a greater extent in the short and medium term, others in the long term, including through the creation of long-term distinctive abilities, unique competencies, and sustainable competitive advantages for industrial companies. The third group of effects is the wider socio-economic effects from the use of a complex of smart production technologies, which can be generally characterised as having a multiplier effect for the entire economy and the properties of positive externalities (external effects). Such a division into three groups of effects seems appropriate from the point of view of the main focus of effects, however, at the same time, it should be noted that in many contexts, the use of a set of smart manufacturing technologies directly or indirectly affects both costs, and the future sales potential of companies, and multipliers for industry and economy level. The boundaries between individual effects can be somewhat blurred.

The importance of systematising the effects in terms of dividing into three groups of effects lies in a more complete and broader understanding of the potential of a complex of smart manufacturing technologies, which can positively influence the dynamics of the implementation and scaling of both the technologies themselves and the business models interconnected with them. This is important from the point of view of the readiness and speed of decision-making both by the industrial enterprises themselves and by other stakeholders, including those influencing the innovation, technology and industrial policies of the state.

2. Group of cost reduction effects at industrial enterprises

To the group of effects of a smart production technology complex can be attributed the following:

• *Reducing the cost of control and monitoring of production processes.* Industrial production engineers can directly monitor and control industrial processes via the Internet, which allows to control engineers to access the production system from anywhere through cloud computing. The cyber-physical system links computational objects to the physical world and its ongoing processes using data processing services available directly on the Internet. An example is microchip and microelectronics company Micron, which has built one of the most advanced integrated platforms for the Internet of Things and analytics. This platform helps the company to monitor processes in real time and identify production anomalies and non-value-adding losses, as well as perform automatic analysis of the causes of such inconsistencies and anomalies. As a result, a number of central operational metrics improved by tens of percent. In particular, the launch of new products accelerated by 20%, and the reduction of unplanned downtime was 30% [Lage, Filho, 2010].

• *Reducing the cost of parts and components.* Additive manufacturing, also known as 3D printing technology, opens up new horizons for smart manufacturing technologies. Additive manufacturing technology is extremely flexible for customisation, rapid prototyping and rapid production of spare parts. It also reduces lead times and machine replacement costs [Lu, 2017]. There is also a reduction in material consumption and a reduction in the weight of parts. Modern products in smart factories are produced using artificial intelligence. An AI-based system can be given initial conditions, and it will work through many options and produce ready-made solutions.

• *More efficient use of production capacity through the ecosystem integration of all elements, including machinery.* Thanks to the integral and synergistic configuration of smart production devices within a single digital technological ecosystem, the success of a production task is determined by the overall availability of all equipment. In addition, thanks to ecosystem integration, a high level of production adaptarion to emerging unforeseen situations is ensured [Kasyanenko et al., 2020].

• *Reducing downtime, losses and waste.* Included in a single digital technological ecosystem, an enterprise has a clear understanding of bottlenecks, machine and equipment performance, and other inefficient operations. With this data, the manufacturer can make adjustments to processes to reduce losses and waste, as well as reduce downtime.

• *Reducing the costs associated with the failure of equipment.* The principle of Predictive Maintenance (predictive maintenance of equipment) is to anticipate problems and failures, and eliminate them in a timely manner [Carvalho et al., 2019]. Setting up a digital twin and using a large number of sensors for machines, machine tools, equipment and devices [Kanawaday, Sane, 2017] makes it possible to recognise faults in time and carry out repairs, as well as to calculate the estimated stock of repair kits with smaller errors [Kasyanenko et al., 2020]. A more advanced tool for predicting equipment activity can reduce the time and material costs of repairs and maintenance, prevent unplanned emergency interruptions in operation, and reduce capital costs in the long term.

• *Reducing reverse engineering costs.* Additive manufacturing facilitates the reverse engineering of any part or product through 3D scanning and allows to design reconfiguration and rapid reproduction for testing and validation [Kang, 2016]. In terms of objective unit costs, additive technologies turn out to be less expensive than traditional ones [Barvinok et al., 2014]. For example, in the aircraft industry, the creation of a rapid simulation platform can reduce the time of design and design development by 20% [Kheifets, Chernova, 2019].

• *Optimisation and information integration of supply chains*. Currently, the concept of open supply chain management (Open Supply Chain Management, OSCM) has particular promise as a new paradigm in the evolution of SCM. Companies can benefit from integrated physical and conceptual resources to improve the efficiency and agility of core supply chain processes, including sourcing, manufacturing, distribution and marketing [Rahmanzadeh et al., 2022]. Deliveries are becoming more flexible as suppliers communicate with warehouses, autonomous or semi-autonomous vehicles and drones in real time. The chains also include mobile robots and cobots (collaborative robots) to automatically perform delivery tasks [Rovito, 2022].

• *Reduced electricity consumption.* A number of studies show a very significant reduction in electricity consumption during the transition to smart manufacturing [Kumar et al., 2021]. For example, industrial companies in Germany were able to reduce electricity consumption by 24% by implementing a program to automate protection on the CSF server [Kasyanenko et al., 2020]. At the same time, it should be noted that smart manufacturing systems will require huge data centers to implement and support their networking needs. Data centers consume a lot of energy, and the resources needed to generate energy have a negative impact on the environment. The following example demonstrates what data center capacity may be required in the future.

The flow of data generated by engines and aircraft is also changing the service and support offerings that jet engine manufacturers can provide. Engines produce a huge amount of information. A single Boeing 737 engine produces 20 terabytes of data every hour in flight. Thus, an eight-hour flight from New York to London in a twin-engine aircraft can generate about 320 terabytes of data [Mathai, 2015].

• *Reduction of the training cost highly qualified engineers and workers.* Virtual reality and augmented reality are already widely used in the production systems of leading international companies to train young engineers and graduates of technical universities who are not very well prepared to work with production processes. The experience of industry leaders shows that through smart manufacturing, graduates and novice professionals are successfully introduced to the production process, mechanisation processes, troubleshooting and maintenance systems. And this form of instruction and training turns out to be even more useful in a number of core competencies than theoretical training in a more academic context [Moon et al., 2019]. For a number of parameters, training new employees and testing the product with demonstrations of various conditions in the augmented environment turned out to be more efficient and time-saving. You can also expect greater involvement and loyalty of employees in the context of using smart manufacturing technologies, increasing their creativity [Gajdzik, Wolniak, 2022], as well as the ability to solve more complex tasks using digital competencies [Paelke, 2014; Ivanov, 2016].

• *Reduction of time and cost in R&D.* Rapid assembly of prototypes helps speed up the production of new products, products of various modifications [Barvinok et al., 2014]. Fast and short communication with customers helps to quickly respond to changes in their preferences and test new products. This makes it possible to reduce unproductive costs in the course of innovation [Hinz, 2013; Guneshka, 2021].

• *Reduction of sunk costs, since the adaptability of production reduces the importance of the factor of specific assets.* Often, specific capital investments associated with interaction with certain customers and suppliers are characterized by a limited ability to reuse the results obtained. The equipment used for smart manufacturing provides a higher level of organization of flexible lines and provides the ability to quickly and efficiently distribute production tasks between individual universal devices depending on the load and level of readiness [Kasyanenko et al., 2020].

• *Reducing the need for working capital.* The reduction in the need for working capital is primarily due to the reduction in inventories and the expansion of opportunities for receiving full or partial prepayment of products from the buyer [Matulik, 2008].

3. Group of effects from increasing the revenue at industrial enterprises

The group of effects that mainly lead to an increase in revenue can primarily include:

• *Improved understanding of shopping habits and requirements.* In today's environment, manufacturers want their customers to share their feedback and personal opinions about products or usage plans. Based on this information, manufacturers tend to focus their product design on meeting the needs of a relatively wide range of customers [Ren et al., 2019]. The processing of large amounts of data helps the manufacturer to determine the current state of the product and the causes of failures, encouraging customers to buy its products, since their purchasing habits and requirements have been taken into account in the design and manufacture. Big data analysis allows you to use the potential of data-driven marketing in the context of production activities to full extent.

• *Better customer satisfaction.* After analysing data from different stages of the technological process, using machine learning and artificial intelligence, manufacturers become more flexible and can quickly change their business models in response to changes in the external environment. Thanks to additive manufacturing and reverse engineering, a quantum leap is being achieved in a number of high-tech industries. For example, in medical manufacturing, additive manufacturing and reverse engineering technologies are used for implants in dentistry and orthopedics to replace damaged body parts. Similar technologies are also used for prototyping, design and testing of structures in civil engineering to ensure cost-effectiveness and customer satisfaction. In this case, modeling and additive technologies make it possible to understand how to provide the best zoning of premises [Negi et al., 2013]. Another example is shoe makers Nike and Under Armor, who are exploring how additive manufacturing can revolutionise shoe manufacturing, ultimately allowing them to tailor sneakers to every athlete's foot.

• *Fast adaptation of products to customer requirements due to production flexibility.* Virtual and augmented reality help in the digital manufacturing process to visualise and test products in a simulated environment for end customers, which enhances the ability to customise a product based on a simulated environment for end customers [Berg, Vance, 2017]. This leads not only to a reduction in a number of costs [Riemer, Totz, 2003], but also increases future sales and profitability. The flexibility of production implies the technical and organisational ability to change equipment quckly within the framework of new tasks, taking into account the requirements of customers and consumers of the final product [Glazkov, 2016].

• *Ability to manufacture small series of specific modifications of products and parts.* Increasing adaptability to changing demand and the speed of launching a new product range into production provides new marketing opportunities and benefits for both large and small and medium-sized innovative enterprises [Barvinok et al., 2014]. Evolving distributed manufacturing systems that replace classical hierarchical control modes are very important for realising an intelligent manufacturing system that can handle growing customisation needs, sudden fluctuations in the supply chain, and is also suitable for small production batches [Lu et al., 2016].

• *Improving the quality of products, reducing manufacturing defects.* All equipment that monitors and controls the production works in real time. Big data is actively used to improve the quality of manufactured products and search for defects in the production process. The presence of such a tool as monitoring of work operations can improve the efficiency of employees. Operations and process monitors have the ability to view data automatically at set intervals on key indicators and control panels to improve process control and product quality, reduce materials for production, reduce resource usage time, and more. It is also important that the standardization of data collection will also make it possible to compare the efficiency of various production facilities, divisions, and assembly lines [Baurina, 2020].

• *Increase in prices and margins of products due to the factor of monopolistic competition.* The economic nature of smart manufacturing from the point of view of the sectoral economy consists in a more pronounced market structure of monopolistic competition. This, in turn, means that more and more industrial companies, thanks to the introduction of a set of "smart production" technologies, can secure such differentiation that will be recognised by the market both in terms of increasing sales growth potential and in terms of achieving high profitability of business lines.

• *Reducing the total cost of ownership of complex technical products for consumers at the stage of product maintenance (digital service).* By streamlining the engineering change process, especially in the context of complex product manufacturing, and by using digital services in the maintenance phase, the total cost of ownership can be reduced. In both B2B and B2C segments, this becomes one of the central competitive advantages and can be used in the course of marketing campaigns. At the same time, the components of a digital service in many industries can turn out to be higher marginal than the supported product. This approach in some cases changes the landscape of entire industries. Probably the most famous and large-scale example of this kind is Apple, whose share of revenue and profit from services (within the software ecosystem) has been growing in recent years, while the "hardware" component has been declining.

• *Increase delivery lead time by providing a more innovative product.* Customers who order an innovative product to fit their specification are willing to wait longer on average, which leads to lower revenue losses, as well as to a reduction in supply chain errors caused by accelerated product assembly [Piller et al., 2004].

4. Group of effects of multiplicative action and positive externalities from the introduction of smart manufacturing technologies

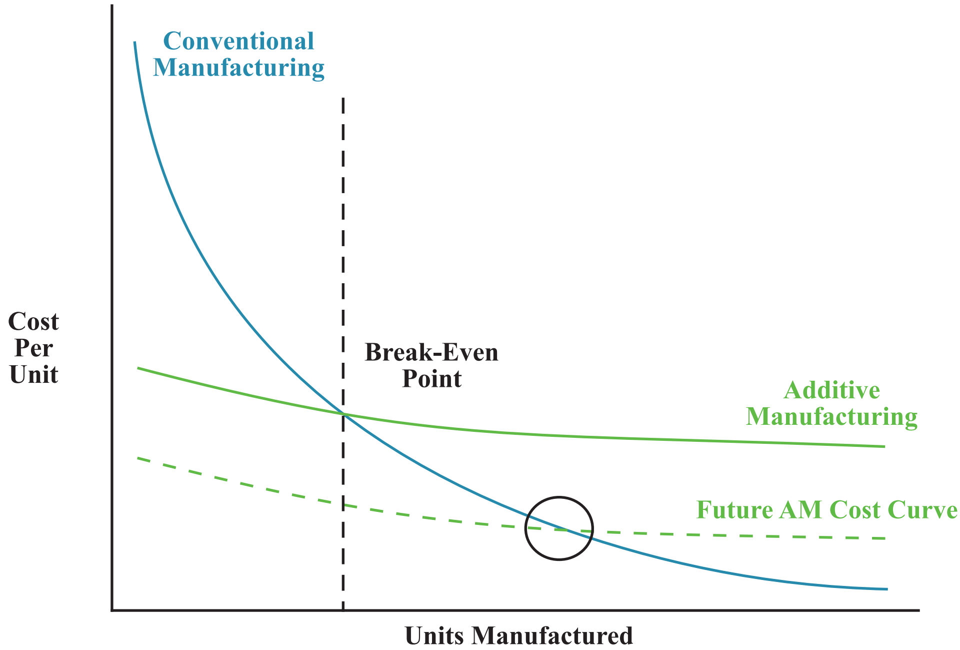
The group of broader socio-economic effects from the use of a complex of "smart production" technologies, which can be generally characterized as having a multiplier effect for the entire economy, as well as the impact as positive externalities (external effects), can primarily be attributed to:

• *Growth of the semiconductor electronics and industrial equipment market.* This growth is accompanied by the development of technologies based on the use of semiconductor electronics. At the same time, imbalances and sectoral crises arise due to a shortage of electronics or equipment, as happened in the automotive industry in 2020–2022 due to a chronic shortage of microelectronic components [Shcherbakov, 2022].

• *Increasing the level of science intensity and manufacturability of products and services in related industries.* The introduction of a complex of technologies "smart production" becomes a driver of scientific and technological development not only in leading industries, but also in related ones [Digital Russia: new reality, 2017], and leads to a higher level of production efficiency, which is characterised by such indicators as the level of innovative activity , the share of high-tech products in GDP, the share of R&D expenditures in GDP. Moreover, the integration model of end-to-end digital transformation of industry based on matrix and industry models allows to build an integration inter-industry digital network in the conditions of the digital economy, within which end-to-end digitalisation of all sectors of the national economy takes place based on common segments of the digital infrastructure and the organisation of functional interactions between them [Zubritskaya , 2018].

• *Intensification of applied science development, especially technical and engineering.* A more complete system of integration of scientific, technical and industrial

Fig. 4. Prospects for reducing the unit costs of small and medium-sized manufacturers through the reduction in the cost of additive manufacturing technologies



Source: [Mahoney, Kota, 2020].

subsystems becomes necessary for the innovative development of the country and industry 4.0. Smart manufacturing, according to a number of researchers, is one of the most suitable landscapes for introducing open innovations [Rahmanzadeh et al., 2022].

• *Changing the structure of employment from low-skilled to highly skilled jobs.* The main effect in terms of the quality of human capital of industrial enterprises is that automation allows manufacturers to start and complete projects with a minimum number of low-skilled workers. Faster access enables higher-skilled employees to focus only on their core tasks. This allows manufacturers to introduce innovative technologies faster without spending additional resources on it. Undoubtedly, the question of the extent to which smart production will generate highly skilled jobs in order to cover the retirement of a large number of professions that become unnecessary in smart production is of great scientific and practical interest and of particular socio-economic significance. Despite the considerable controversy of the issue and various estimates, including conservative and pessimistic ones, the average estimates are encouraging [Jagannathan et al., 2019; Grenčíková et al., 2020; Anackovski et al., 2021], especially if we consider the overall reduction in man-hours in high-tech industries as part of the general economic trend towards a shorter workweek. In countries that have already institutionalised a shorter workweek to varying degrees (for example, in Germany, Austria, France, where the working week in industrial enterprises is about 33 hours), automation is not perceived with hostility, but with an understanding of its long-term benefits in terms of the quality of life of the personnel of enterprises.

• *Increasing demand for IT professionals.* This professional group in the broad definition should be singled out separately, since its increase in the last few years has become an extremely significant priority of state policy in the field of employment, education and retraining of personnel in many countries, including Russia. Further development and implementation of intelligent manufacturing systems will create additional demand for information technology specialists. The information technology sector will need skilled people to design, develop, run and maintain network programs. Thus, the number of jobs in the field of information technology will grow. However, in manufacturing plants, unskilled operators and other workers are at risk of losing their jobs.

• *Increasing labor productivity in industry and the economy as a whole.* This effect is largely a product of the shift in smart industry employment towards a more highly skilled workforce and a sharp decline in the employment of low-skilled workers. However, it is necessary to note other components, due to which this effect is more pronounced and systemic within the framework of the smart production paradigm. Enterprises create separate performance

Table 2
Systematization of the socio-economic effects from the implementation of smart production technologies

Cost reduction effects	Revenue increase effects	Multiplier effects and positive externalities
Reducing the cost of control and monitoring of production processes	Improved understanding of shopping habits and requirements	Growth of the semiconductor electronics and industrial equipment market
Reducing the cost of parts and accessories	Better customer satisfaction	Increasing the level of science intensity and manufacturability of products and services in related industries
More efficient use of production capacity through ecosystem integration	Fast adaptation of products to customer requirements due to production flexibility	Intensification of the applied science development, especially technical and engineering
Reduce downtime, losses and waste	Ability to manufacture small series of specific modifications of products and parts	Changing the structure of employment towards highly skilled jobs
Reducing the costs associated with equipment failure	Improving the quality of products, reducing manufacturing defects	Increasing demand for IT professionals
Reducing reverse engineering costs	Increase in prices and margins of products due to the factor of monopolistic competition	Increasing labor productivity in industry and in the economy as a whole
Optimisation and information integration of supply chains	Reduction for consumers of the total cost of ownership of complex technical products at the digital service stage	Reduction of economic and social damage from non-compliance with safety regulations
Reduced electricity consumption	Increase delivery lead time by providing a more innovative product	Broader transition of industries and sectors of the economy to PaaS business models
Reducing the cost of training highly qualified engineering and working specialists		Increasing the share of medium and small enterprises in the volume of industrial production
Time reduction and cost in R&D		Increasing the investment activity of enterprises
Reduction of sunk costs by reducing the importance of the factor of specific assets		Improving the quality and transparency of management
Reducing the need for working capital		Improving corporate governance and ESG factors in industrial companies
Increasing the environmental sustainability of production		

Source: compiled by the author.

management systems [Bagautdinova, Bagautdinova, 2018].

• *Reduction of economic and social damage from non-compliance with safety regulations.* A number of smart manufacturing technologies, in particular computer vision, allow not only to optimise processes, but also to control the actions and operations of personnel at a new level in terms of meeting safety requirements [Tarasova, Shparova, 2021; Rovito, 2022]. However, the point is not only in effective control, but also in the fact that the complex of "smart production" technologies allows, already within the framework of workplace design, to ensure the highest prioritisation of safety in the workplace. Research on the effect of reducing worker injuries and improving their overall well-being and quality of life is of particular interest. In the context of the activities of Russian industrial enterprises, this is especially important, since so far in most industries the levels of injury to workers and working conditions in terms of health hazards can hardly be called satisfactory, given the already existing potential for the use of high technologies. Here are some examples of private smart manufacturing technologies that have taken workplace safety to a new level. The first example is the progress in the robotic environment, where, thanks to a number of technologies, the biometric data of the operator is also included in the control loop. Thanks to this, it is possible to implement a personalised security strategy based on the role of a person, physical condition, speed, and other parameters [Wang, Wang, 2020]. A second example is that a number of smart technologies, especially augmented reality, are improving the quality of safety training [Deac et al., 2017]. As a third example, dynamic self-organising security systems are being developed to help an engineer working in a smart manufacturing facility discover all security-related devices and automatically generate a suitable security configuration. This configuration will be automatically deployed to the system after adaptation and verification by a safety engineer. The proposed self-organising security system simplifies security configuration in a dynamic environment. Therefore, this not only improves workplace safety, but also reduces engineering effort and equipment downtime, which in turn improves profitability [Etz et al., 2020].

• *Wider transition of industries and sectors of the economy to PaaS (Product as a Service) business models.* At first glance, this may seem somewhat counterintuitive, but the complex of smart manufacturing technologies stimulates not only innovative technological and product components in the industry itself, but also a more integral and holistic inclusion of service components in a common product shell, especially services with a high level of digitalisation. This is especially important both for the competitiveness of Russian industrial enterprises and for the marginality of their business. Service components are on average more cost-effective. Smart manufacturing creates a much greater variety of niches for building new business models, such as paying monthly subscriptions instead of hardware sales (also known as "product as a service").

• *Increasing the share of medium and small enterprises in the volume of industrial production.* This effect largely depends on the contexts of individual industries, and in most cases it should not be an end in itself. Nevertheless, many experts point out that many sectors of Russian industry are characterised by a high concentration of large-scale industries and that it does not correspond to the parameters of a progressive sectoral structure. Increasing adaptability to changing demand and the speed of launching a new product range as one of the central advantages of the "smart production" technology complex provides new marketing opportunities and benefits for both large and small and medium-sized innovative enterprises [Barvinok, Smelov, Kokareva, Malykhin, 2014]. Graphically, the advantage of introducing digital technologies (primarily additive manufacturing) for small and medium-sized industrial companies is shown in Fig. 4. As AM technology becomes more versatile in terms of materials, part sizes, and reliability, and as more companies enter the 3D printer market, prices are falling. Small hobby 3D printers from companies like MakerBot are available for less than $3,000. Industrial-scale printers using polymers or ceramics cost less than $95,000, and printers using metals around $400,000. However, new machines from Desktop Metal and HP promise to cut price levels significantly [Mahoney, Kota, 2020].

• *Increasing the investment activity of enterprises, including small and medium ones.* Investment growth can be expected in all types of fixed assets (3D printing machines), intangible assets (software, licenses, patent), research and development. However, empirical studies of small and medium-sized enterprises show that they have unsustainable behavior in terms of investment in information and communication technologies and need external support to integrate digital transformation into the overall strategy of the firm [Ulas, 2019]. However, it is not only about support, but also about understanding the potential of smart manufacturing technologies, including for assessing the investment feasibility of various solutions. Digital twin technologies are especially useful in this regard. Digital twin technologies are used to gather information for a realistic economic evaluation of full automation solutions, to support and encourage investment to realize the potential of digital transformation of manufacturing. Technologies include modeling, data analysis, and behavioral models that are used to assess impact, implementation scenarios, eliminate the need for physical prototypes, reduce development time, and improve quality [Caccamo, 2022]. Also, in a recent study, taking into account the problems of the activities of small and medium-sized enterprises in conditions of high uncertainty of digital transformation processes, a modification of the value stream mapping method (VSM) was proposed to evaluate intelligent production decisions, in which the emphasis is on information flows and integration required key performance indicators [Martin, 2020].

• *Improving the quality and transparency of management.* Technological and organisational innovations occur both sequentially and simultaneously and complement each other in the context of the transition to smart manufacturing. The interaction between the two types of innovation is complex. Most manufacturers have old systems for collecting and processing information. New systems must be upgraded to the next generation of performance. Based on these new ideas and a better understanding of the business, it becomes possible to develop new strategies [Baurina, 2020].

• *Improvement of corporate governance and ESG factors in industrial companies.* Despite the importance of corporate transformation towards industry 4.0 (Corporate Transformation Toward Industry 4.0, CTTI4.0), to date, research on how companies report CTTI4.0 information in their annual reports and how this affects financial performance is scarce. However, recent pioneering work [Alkaraan et al., 2022] in this area found that CTTI4.0 disclosure has a positive impact on the financial performance of industrial companies. In addition, environmental, social and governance (ESG) practices have been found to favorably influence the relationship between CTTI4.0 disclosures and financial performance.

• *Increasing the environmental sustainability of production.* By intelligently managing the entire manufacturing process, smart manufacturing systems reduce waste, overproduction and energy consumption. The manufacturing system automatically orders material or parts from its suppliers when needed. In times of lower sales volumes, fewer raw materials are ordered. Another example of environmental sustainability is that manufacturing companies are connected to power plants and can schedule energy-intensive tasks with the natural overproduction of energy from wind or solar energy. Surplus energy can be used by other companies or private households in the immediate surroundings. Thanks to intelligent energy management systems and network technologies, renewable energy sources can be used more efficiently.

5. Systematisation of socio-economic effects of the introduction of smart manufacturing technologies in tabular form

It seems appropriate to present the socio-economic effects of the introduction of smart manufacturing technologies identified above for three groups in tabular form (Table 2.). Some of the extended effect titles have been shortened for tabular presentation.

6. Conclusions and possible directions for further research

As a result of the study, 12 cost reduction effects, 8 revenue increase effects and 13 multiplier effects and the nature of positive external effects from the introduction of a set of smart production technologies in industrial enterprises are summarised and highlighted. Of particular importance at present are the areas of research on the socio-economic effects of the introduction of smart manufacturing technologies, since some improvements at the intersection of production and social transformation are currently insufficiently studied, in contrast to the actual production effects, many of which have been studied in sufficient detail by the scientific and expert communities.

It seems that the systematisation, classification, differentiation and quantitative assessment of the various effects of the "smart production" complex can and even in a certain sense (in the context of the tasks of modernising the economy and industry of the Russian Federation) should become a separate subject area at the intersection of performance management (Performance Management) and smart production (Smart Manufacturing). The question of the feasibility and prospects of building a certain composite index of the level of maturity and / or the effectiveness of the introduction of smart manufacturing technologies at the level of industry or individual industries and sectors may deserve special attention.

From the point of view of the state industrial policy, it is important to understand the priority of ensuring the wider use of a set of smart manufacturing technologies. State industrial policy instruments and a favorable institutional environment can help with the rapid scaling of a set of smart manufacturing technologies across a wide range of enterprises in various industries and sectors of the economy.

References

Bagautdinova N.G., Bagautdinova R.A. (2018). New competitive advantages in the context of digitalization. *Innovation*, 8: 80-83. (In Russ.)

Barvinok V.A., Smelov V.G., Kokareva V.V., Malykhin A.N. (2014). Progressive technologies in mechanical engineering. *Problems of Mechanical Engineering and Automation,* 4: 142-149. (In Russ.)

Baurina S.B. (2020). Technologies of the future: smart manufacturing in industry. *Bulletin of the Russian University of Economics G.V. Plekhanov,* 17(2): 123-132. DOI: http://dx.doi.org/10.21686/2413-2829-2020-2-123-132. (In Russ.)

Glazkov B. (2016). The possibilities of the industrial Internet. *Springboard to Success,* 7: 24-27. (In Russ.)

Zubritskaya I.A. (2018). Digital transformation of industrial enterprises of the Republic of Belarus: Economic content, types and goals. *Digital Transformation,* (3): 5-13. (In Russ.)

Ivanov D. (2016). A testing ground for advanced manufacturing technologies. *Springboard to Success,* 7: 14-16. (In Russ.)

Kasyanenko E.O., Shimchenko A.V., Salkutsan S.V. (2020). Comparative analysis of the traditional production model and “smart factories”. *Journal of Legal and Economic Studies,* 3: 7-17. (In Russ.)

Merzlikina G.S. (2021). Economic efficiency of “smart production”: From targets to regulation. *Bulletin of ASTU. Economy,* 3. (In Russ.)

Myasnikova O.V. (2020). Theoretical and conceptual approaches to the formation of the production and logistics system of “smart” production as a socio-cyber-physical system. *Economy. Control. Innovation,* 1(7): 29-35. (In Russ.)

Tarasova N.N., Shparova P.O. (2021). *Top 15 digital technologies in the industry.* https://issek.hse.ru/mirror/pubs/share/494926392.pdf. (In Russ.)

Titov S.A., Titova N.V. (2022). Estimation of economic effects from customization of products of Russian industrial enterprises. *Strategic Decisions and Risk Management,* 13(1): 26-36. DOI: 10.17747/2618-947X-2022-1-26-36. (In Russ.)

Trachuk A.V., Linder N.V., Tarasov I.V., Nalbandyan G.G., Khovalova T.V., Kondratyuk T.V., Popov N.A. (2018). *Transformation of industry in the conditions of the fourth industrial revolution: monograph.* St. Petersburg, Real’naya ekonomika. (In Russ.)

Trachuk A.V., Linder N.V. (2020). The impact of industry 4.0 technologies on increasing productivity and transforming the innovative behavior of industrial companies. *Strategic Decisions and Risk Management,* 2(11): 132-149. (In Russ.)

Kheifets B.A., Chernova V.Yu. (2019). Foreign programs of smart reindustrialization. *ECO*, 8: 118-140. DOI: 10.30680/ECO0131-7652-2019-8-118-140. (In Russ.)

Digital Russia: A new reality (2017). Digital McKinsey. https://www.mckinsey.com/ru/~/media/mckinsey/locations/europe%20and%20middle%20east/russia/our%20insights/digital%20russia/digital-russia-report.pdf. (In Russ.)

Digital transformation of industries: Starting conditions and priorities (2021). Moscow, NRU HSE. https://conf.hse.ru/mirror/pubs/share/463148459.pdf?ysclid=l2yt4ijpgh. (In Russ.)

Digital economy 2022: A brief statistical compendium (2022). Moscow, NRU HSE. https://issek.hse.ru/mirror/pubs/share/552091260.pdf. (In Russ.)

Shcherbakov G.A. (2022). The global shortage of semiconductor components as a source of the current crisis in the global automotive industry. *MID (Modernization. Innovations. Development),* 13(2): 270-287. https://doi.org/10.18184/2079-4665.2022.13.2.270-287. (In Russ.)

Alkaraan F., Albitar K., Hussainey K., Venkatesh V.G. (2022). Corporate transformation toward Industry 4.0 and financial performance: The influence of environmental, social, and governance (ESG). *Technological Forecasting and Social Change,* 175: 121423. https://doi.org/10.1016/j.techfore.2021.121423.

Anackovski F., Kostov M., Pasic R., Kuzmanov I. (2021). The impact of Industry 4.0 on education and future jobs (2021). In: *56th International Scientific Conference on Information, Communication and Energy Systems and Technologies (ICEST):* 185-188. DOI: 10.1109/ICEST52640.2021.9483516.

Berg H., Le Blévennec K., Kristoffersen E., Strée B., Witomski A., Stein N., Bastein T., Ramesohl S., Vrancken K. (2020). *Digital circular economy as a cornerstone of a sustainable European industry transformation.* European Circular Economy Research

Alliance (ECERA). https://ss-usa.s3.amazonaws.com/c/308476495/media/19365f987b483ce0e33946231383231/201023%20ECERA%20White%20Paper%20on%20Digital%20circular%20economy.pdf.

Berg L.P., Vance J.M. (2017). Industry use of virtual reality in product design and manufacturing: A survey. *Virtual Reality,* 21(1): 1-17.

Bughin J., Catlin T., Hirt M., Willmott P. (2018). Why digital strategies fail. *McKinsey Quarterly,* Jan.

Caccamo C., Pedrazzoli P., Eleftheriadis R., Magnanini M.C. (2022). Using the process digital twin as a tool for companies to evaluate the return on investment of manufacturing automation. *Procedia CIRP,* 107: 724-728. https://doi.org/10.1016/j.procir.2022.05.052.

Carvalho T.P., Soares F.A., Vita R., Francisco R.P., Basto J.P., Alcalá S.G. (2019). A systematic literature review of machine learning methods applied to predictive maintenance. *Computers & Industrial Engineering,* 137: 106024. https://doi.org/10.1016/j.cie.2019.10602.

Deac C.N., Popa C.L., Ghinea M., Cotet C.E. (2017). Using augmented reality in smart manufacturing. In: *Proceedings of the 28th DAAAM International Symposium:* 0727-0732. Vienna, DAAAM International. 10.2507/28th.daaam.proceedings.102

Etz D., Frühwirth T., Kastner W. (2020). Flexible safety systems for smart manufacturing. In: *25th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA):* 1123-1126. DOI: 10.1109/ETFA46521.2020.9211905.

Gajdzik B., Wolniak R. (2022). Smart production workers in terms of creativity and innovation: The implication for open innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(2): 68. https://doi.org/10.3390/joitmc8020068.

Geerts R. (2016). The smart manufacturing elevator pitch, literally! *MESA International's.* https://blog.mesa.org/2016/03/the-smart-manufacturing-elevator-pitch.html.

Grenčíková A., Kordoš M., Berkovič V. (2020). The impact of Industry 4.0 on jobs creation within the small and medium-sized enterprises and family businesses in Slovakia. *Administrative Sciences,* 10(3): 71. https://doi.org/10.3390/admsci10030071.

Guneshka D. (2021). *Benefits of product personalization.* https://www.iplabs.de/en/blog/blog/benefits-of-product-personalization.

Hinz P. (2013). *Effects of mass customization on manufacturing.* https://www.adaptalift.com.au/blog/2013-06-17-effects-of-mass-customisation-on-manufacturing.

Jagannathan S., Ra S., Maclean R. (2019). Dominant recent trends impacting on jobs and labor markets - an overview. *International Journal of Training Research,* 17(sup1): 1-11. DOI: 10.1080/14480220.2019.1641292.

Kanawaday A., Sane A. (2017). Machine learning for predictive maintenance of industrial machines using iot sensor data. In: *8th IEEE International Conference on Software Engineering and Service Science (ICSESS), IEEE*: 87-90. https://doi.org/10.1109/ICSESS.2017.8342870.

Kang H.S. (2016). Smart manufacturing: Past research, present findings, and future directions. *International Journal of Precision Engineering and Manufacturing Green Technology*, 3(1): 111-128.

Kumar M., Shenbagaraman V.M., Shaw R.N., Ghosh A. (2021). Predictive data analysis for energy management of a smart factory leading to sustainability. In: Favorskaya M.N., Mekhilef S., Pandey R.K., Singh N. (eds.). *Innovations in electrical and electronic engineering. Lecture notes in electrical engineering,* 661. Singapore, Springer. https://doi.org/10.1007/978-981-15-4692-1_58.

Lage M.J., Filho M.G. (2010). Variations of the Kanban system: Literature review and classification. *International Journal of Production Economics,* 125(1): 13-21.

Lu Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration,* 6: 1-10.

Lu Y., Morris K.C., Frechette S. (2016). Current standards landscape for smart manufacturing systems. *National Institute of Standards and Technology,* 8107.

Mahoney T.C., Kota S. (2020). *Smart manufacturing: Premier for small manufacturers,* March. Report MF-TR-2020-0301. www.MForesight.org.

Martin N.L., Dér A., Herrmann C., Thiede S. (2020). Assessment of smart manufacturing solutions based on extended value stream mapping. *Procedia CIRP,* 93: 371-376. https://doi.org/10.1016/j.procir.2020.04.019.

Mathai P. (2015). *Big data: Catalyzing performance in manufacturing.* Wipro, Jan., 8. http://www.wipro.com/documents/Big%20Data.pdf.

Matulik P. (2008). *Mass customization.* Zlin, Tomas Bata University. http://195.178.95.140:8080/bitstream/handle/10563/6523/matul%C3%ADk_2008_dp.pdf?sequence=1&isAllowed=y.

Moon S., Becerik-Gerber B., Soibelman L. (2019). Virtual learning for workers in robot deployed construction sites. In: *Advances in informatics and computing in civil and construction engineering.* Proceedings of the 35th CIB W78 2018 Conference: IT in Design, Construction, and Management. Springer, 889-895.

Negi S., Dhiman S., Sharma R.K. (2013). Basics, applications and future of additive manufacturing technologies: A review. *Journal of Manufacturing Technology Research,* 5(1/2): 75.

Odważny F., Szymańska O., Cyplik P. (2018). Smart factory: The requirements for implementation of the Industry 4.0 solutions in FMCG environment-case study. *LogForum,* 14(2): 257-267. http://doi.org/10.17270/J.LOG.2018.253.

Paelke V. (2014). Augmented reality in the smart factory: Supporting workers in an Industry 4.0. environment. In: *Proceedings of the 2014 IEEE emerging technology and factory automation (ETFA),* IEEE, 1-4.

Phuyal S., Bista D., Bista R. (2020a). Challenges, opportunities and future directions of smart manufacturing: A state of art review. *Sustainable Futures,* 2: 100023. https://doi.org/10.1016/j.sftr.2020.100023.

Phuyal S., Bista D., Izykowski J., Bista R. (2020b). Design and implementation of cost-efficient SCADA system for industrial automation. *International Journal of Engineering and Manufacturing,* 10(2): 15-28. 10.5815/ijem.2020.02.02.

Piller F.T., Moeslein K., Stotko C.M. (2004). Does mass customization pay? An economic approach to evaluate customer integration. *Production Planning & Control,* 15(4): 435-444. doi:10.1080/0953728042000238773.

Rahmanzadeh S., Pishvaee M.S., Govindan K. (2022). Emergence of open supply chain management: the role of open innovation in the future smart industry using digital twin network. *Annals of Operations Research,* preprint. https://doi.org/10.1007/s10479-021-04254-2.

Ren S., Zhang Y., Liu Y., Sakao T., Huisingh D., Almeida C.M. (2019). A comprehensive review of big data analytics throughout product lifecycle to support sustainable smart manufacturing: A framework, challenges and future research directions. *Journal of Cleaner Production,* 210: 1343-1365.

Riemer K., Totz C. (2003). The many faces of personalization. In: *The Customer Centric Enterprise*: 35-50. Berlin, Heidelberg, Springer Berlin Heidelberg.

Rovito M. (2022). *Smart manufacturing: The future of making is digital.* https://redshift.autodesk.com/smart-manufacturing/.

Schallmo D., Willams C.A., Boardman L. (2018). Digital transformation of business models-best practice, enabler, and roadmap. *International Journal of Innovation Management,* 21(8): 1740014. https://doi.org/10.1142/9781786347602_0005.

Strozzi F., Colicchia C., Creazza A., Noè C. (2017). Literature review on the 'Smart Factory'concept using bibliometric tools. *International Journal of Production Research,* 55(22): 6572-6591. http://doi.org/10.1080/00207543.2017.1326643.

Ulas D. (2019). Digital transformation process and SMEs. *Procedia Computer Science,* 158: 662-671. https://doi.org/10.1016/j.procs.2019.09.101.

Wang X.V., Wang L. (2020). Safety strategy in the smart manufacturing system: A human robot collaboration case study. In: *Proceedings of the ASME 2020 15th International Manufacturing Science and Engineering Conference,* 2: Manufacturing Processes; Manufacturing Systems; Nano/Micro/Meso Manufacturing; Quality and Reliability. September 3. V002T07A026. ASME. https://doi.org/10.1115/MSEC2020-8427.

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Formation of a conceptual model of sustainable development of the organization: Strategy and development prospects

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Abstract

The purpose of this article is to identify possible approaches to the development of an Organizational sustainability conceptual model and to present this model for discussion by the expert community. To achieve this goal, the author suggests defining the structure and description of individual elements of sustainability, as well as establishing the relationship between them. The sustainability model will serve as a conceptual basis for the development of international and national standards aimed at certain aspects of organizational sustainability, will assist organizations in developing and implementing sustainability strategies and goals, managing ESG factors and associated risks and opportunities, as well as preparing non-financial reporting.

Keywords: sustainability, ESG, key indicators, risk management, non-financial reporting.

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1. Standardisation of sustainable development in Russia

Since 2021, the topic of sustainable development and the ESG agenda has begun to gain popularity in Russia: forums and conferences are held, various information materials appear in print media and on the Internet. However, in the author's opinion, there is a lack of a conceptual standardised approach to activities in the field of sustainable development and ESG.

The term "ESG factors" appeared in the report "Who cares wins. Connecting financial markets to a changing world", prepared in 2004 under the auspices of the UN Global Compact at the request of UN Secretary-General Kofi Annan. ESG factors (Environmental, Social and Governance factors) are factors related to the environment (including environmental and climate change factors, E), society (social factors, S) and corporate governance factors (G). Sustainable development in a global context is understood as development that meets the needs of the present without compromising the ability of future generations to meet their own needs [Bank of Russia Information Letter No. IN-06-28/96.., 2021].

Russia has never sit on the sidelines from global processes towards the standardisation of sustainable development. Suffice it to say that already more than 10 years ago, namely on June 19, 2012, the Technical Committee for Standardsation "Sustainable Development" (TC 115) was formed, until April 2022 it was called "Sustainable Development of Administrative -Territorial Entities".

On April 5, 2022, the Federal Agency for Technical Regulation and Metrology (Rosstandart) issued Order No. 866 "On organising the activities of the technical committee for standardisation "Sustainable Development"". This order approved the structure of the committee, which includes subcommittees SC 1 "Sustainable cities and communities" and SC 2 "Sustainable organisations" [Order of the Federal Agency.., 2022].

During 2012-2021, the focus of the committee's activities was shifted to the sustainable development of cities and communities, and the concept of sustainable development of organisations received little attention. At the meeting of TC 115 "Sustainable Development" on July 7, 2022, proposals were considered for the development of the activities of TC 115 and the development of national standards, including the management system for the sustainable development of organisations, indicators and their evaluation, reporting on the achievement of sustainable development goals, sustainable supply chain management.

Before proceeding with the development of standards aimed at certain aspects of sustainable development of organisations, it seems appropriate to develop and submit for discussion by the expert community a conceptual model of sustainable development of an organisation.

2. Purpose and structure of the sustainable development model

The conceptual model is a description of the structure and objects, as well as the relationships between them. The model facilitates understanding of the principles of sustainable development and ESG, serves as a basis for the development and implementation of the sustainable development strategy and goals, management of ESG factors and associated risks and opportunities, as well as the preparation of non-financial reporting.

The following elements should be included in the organisation's sustainable development model:

1. The structure and functions of the company's management, including management bodies, structural divisions, resources, powers (in relation to ESG).
2. Strategy for sustainable development.
3. Goals of sustainable development.
4. Key financial and non-financial performance indicators and metrics.
5. Sustainable development projects (including green, adaptive, social).
6. Programs, plans and activities in the field of sustainable development.
7. Risk management system, including consideration of ESG factors, risks and opportunities.
8. The system for ensuring the continuity of the organisation's activities, including incident management, analysis and prevention of consequences, contingency plans.
9. Interaction with stakeholders and ensuring compliance with the requirements for the company's activities.
10. Internal control, compliance, internal audit.
11. Non-financial reporting, including assessment of the impact of the company's activities on ESG factors and the impact of ESG factors on the company.
12. Working with suppliers and accounting for greenhouse gas emissions - direct and indirect (carbon footprint).

Aspects of sustainable development and ESG factors should also be taken into account in:

- the organisation's operations, including management procedures and practices, business processes, plans and activities;
- system of incentives and remuneration of personnel;
- supply chain management.

3. Individual elements of the sustainable development model

1. The structure and functions of the company's management, including management bodies, structural divisions, resources, powers (in relation to ESG)

ESG factors and sustainable development issues should be taken into account already at the stage of formation of governing bodies. Many companies form a sustainable development committee under the board of directors, introduce new structural units, such as the chief sustainability officer (CSO), the sustainable development department, etc.

The relevant management bodies and structural units should have the necessary competencies, resources and powers to implement the ESG principles, assess risks and opportunities, make decisions, and allocate resources.

It is recommended to document the responsibility and authority in the organisation in terms of sustainable development and ESG, which can be done both by developing new documents and by amending existing ones. Such documents can be:

- concept or business model of sustainable development;
- documents that form the ESG corporate culture, such as sustainability policy, corporate governance code, personnel policy;
- system of incentives, evaluation of results and remuneration of personnel;
- communication procedures (internal and external interaction) on ESG issues;
- procedures for taking into account ESG factors and associated risks and opportunities;
- control procedures;
- procedures for preparing non-financial reporting.

It is necessary to organise regular review by management bodies of plans and reports on the implementation of ESG principles and functions, while taking into account both quantitative criteria and qualitative assessments.

2. Strategy for sustainable development

To take into account all elements of sustainable development, it is recommended to form (or update) the company's business model covering the mission, strategy, business processes and procedures, taking into account ESG factors. The sustainable development strategy itself can be both a separate document and a block as part of a corporate strategy dedicated to ESG and sustainable development issues.

The influence of ESG factors, risks and opportunities on the company's strategy, plans and development scenarios should be taken into account. It is desirable to provide for this in all available blocks of the strategy (product, portfolio, regional, industry, operational), taking into account the appetite for accepted risks and the quality of the risk management system.

The strategic decisions made on the management of activities, taking into account ESG factors, must be specified in the planned performance indicators of departments and employees, in conjunction with the incentive and remuneration system, with reflection in accounting and reporting.

3. Sustainable Development Goals

Strategic decisions in the field of ESG must be specified in the performance targets of departments and employees, followed by monitoring and reporting on the implementation of plans.

The company's sustainable development goals should be linked with the Sustainable Development Goals (UN SDGs), the goals of the Paris Climate Agreement, and the national goals enshrined in state strategic planning documents. The sustainable development goals need to be linked to business processes, projects and activities.

4. Key financial and non-financial performance indicators and metrics

It is necessary to develop and link indicators that reflect the participation of divisions and personnel of the company in achieving corporate sustainable development goals, progress in ESG development, indicators of ESG risks and opportunities, direct and indirect emissions, and other significant indicators.

It is important to establish metrics and formulas for calculating indicators, organise the management of financial and non-financial performance indicators, analyse their dynamics, and regularly assess the compliance of performance results with the planned key indicators.

5. Sustainable development projects (including green, adaptive, social)

It is important to organise the accounting of projects in the field of sustainable development, the formation of a register of sustainable projects of the company. When initiating and launching projects, it is necessary to correlate them with the criteria of green, adaptation, social projects (based on the relevant taxonomies), and also adhere to the principles of responsible investment.

The definition of green and adaptation projects is established by the goals and main directions of sustainable development of the Russian Federation (approved by the Decree of the Government of the Russian Federation dated July 14, 2021 No. 1912-r) [Government Decree .., 2021], the criteria for green and adaptation projects are approved by the Decree of the Government of the Russian Federation dated September 21 .2021 No. 1587. The specified resolution defines the areas of activity in which green projects can be implemented: waste management, energy, construction, industry, transport and industrial equipment, water supply and sanitation, natural landscapes, rivers, water bodies and biodiversity, agriculture. There are six areas for adaptation projects: waste management, energy, sustainable infrastructure, industry, transport and industrial equipment, and agriculture [Government Decree.., 2021].

For each of the areas of activity, specific qualitative and quantitative criteria for project compliance have been developed, allowing them to be classified as green or adaptive. Among the criteria, much attention is paid to compliance with resource and energy efficiency indicators according to information and technical reference books on the best available technologies.

The taxonomy of social projects, which VEB.RF is developing jointly with the Ministry of Economic Development of the Russian Federation, should be adopted by the end of 2022. The taxonomy project contains 10 main areas for the implementation of social projects: health care, education, employment, affordable housing, sports, culture, art and tourism, food availability, infrastructure.

6. Programs, plans and activities in the field of sustainable development

The sustainable development agenda needs to be integrated into the daily activities of all involved departments and ensure their interaction on ESG issues.

There should be clear procedures for the formation, coordination and approval of programs and plans, setting goals (measures) in the field of sustainable development and monitoring their implementation with an assessment of effectiveness.

7. Risk management system, including consideration of ESG factors, risks and opportunities

Let's define ESG risks (opportunities) based on [Vysokov, 2021]: these are environmental, social or management events or conditions that can have a significant impact (negative or positive) on the assets, financial position, profit and reputation of the company. For environmental risks, it is recommended to use the more precise term “climate and environmental risks”, which are subdivided into physical risks and transitional risks.

ESG risks are grouped in the following areas:

E - climate and environmental risks, including physical risks: catastrophes (hurricanes, floods, fires, heat waves), chronic changes (temperature changes, sea level rise, reduction of water resources, loss of biodiversity and changes in land productivity and soils), transitional risks (legislative changes, technological progress, changes in consumer behavior, prices, tariffs, taxes, regulation of a low-carbon economy);

S - social risks, including the impact of changes in social proportions (equality, health, safety, labor relations, migration, communities), the quality and safety of the products, services and working conditions provided;

G - managerial risks, including the procedures for making managerial decisions (subordination, fairness, honesty, transparency, rights, obligations, remuneration of managers) [Vysokov, 2021].

The company should have procedures for identifying, managing and controlling ESG risks: it is desirable that they could be integrated into the overall risk management system, but they can be separate, and their interaction with other risks will need to be taken into account.

It is necessary to organise the identification and accounting of ESG factors, ensure their integration into the company's business model and mechanisms for the relationship of ESG factors with risks and opportunities. Relationships of risks and opportunities with the company's operations (business processes), projects, products (services), supply chain, relationships with counterparties should be established.

It is necessary to develop mechanisms for assessing the impact of the company's activities on the environment (including the climate), the social sphere (including the observance of human rights) and the economy. On a regular basis, the impact of ESG risks on the current operating activities of the company and future investment projects should be assessed and analysed, ESG risks and opportunities should be assessed and reassessed, and a strategy for managing them should be determined. Convenient tools include ESG risk dashboards and interactive ESG risk reports.

8. System for ensuring the continuity of the organisation's activities, including incident management, analysis and prevention of consequences, contingency plans

The company must implement a mechanism for identifying potential events (incidents) that can lead to business disruption, material or other losses, emergency or crisis.

Business continuity plans and procedures need to be in place to capture past incidents and minimise their impact, including timely disaster recovery of physical assets, IT systems, personnel security and work environment.

It is recommended to create in advance templates for contingency plans and responses to unforeseen events that cannot be predicted and prevented, but which need to be promptly responded to, including a structured exchange of information with emergency services and a list of restoration work.

9. Stakeholder Engagement and Ensuring Company Compliance

It is necessary to organise the identification and accounting of mandatory requirements for the company's activities (which include legislative, regulatory, regulatory) and obligations voluntarily accepted by the company. Voluntary standards include international, national and industry standards, standards in the field of sustainable development and corporate governance, standards in the field of environmental protection, energy efficiency, health and safety, social responsibility, quality management.

It will be useful for the company to maintain a database of internal and external documents containing ESG requirements. It is important not only to identify the various environmental, social and governance aspects of the company's activities, but also to establish the relationship between them, as well as with the financial and non-financial performance of the company.

10. Internal control, compliance, internal audit

Compliance should monitor and control compliance with the requirements of stakeholders, internal control services check the accounting of ESG factors, the implementation of established control procedures. Internal audit checks how ESG risks and opportunities are managed, and makes proposals for revising the organisational structure and specific functions. Mechanisms for fixing inconsistencies (violations) and conducting analysis, developing corrective measures and monitoring their implementation should be put into practice.

11. Non-financial reporting, including assessment of the impact of the company's activities on ESG factors and the impact of ESG factors on the company

The results of the company's work on the implementation of environmental, social and managerial responsibility should be reflected in the financial statements and non-financial information for stakeholders.

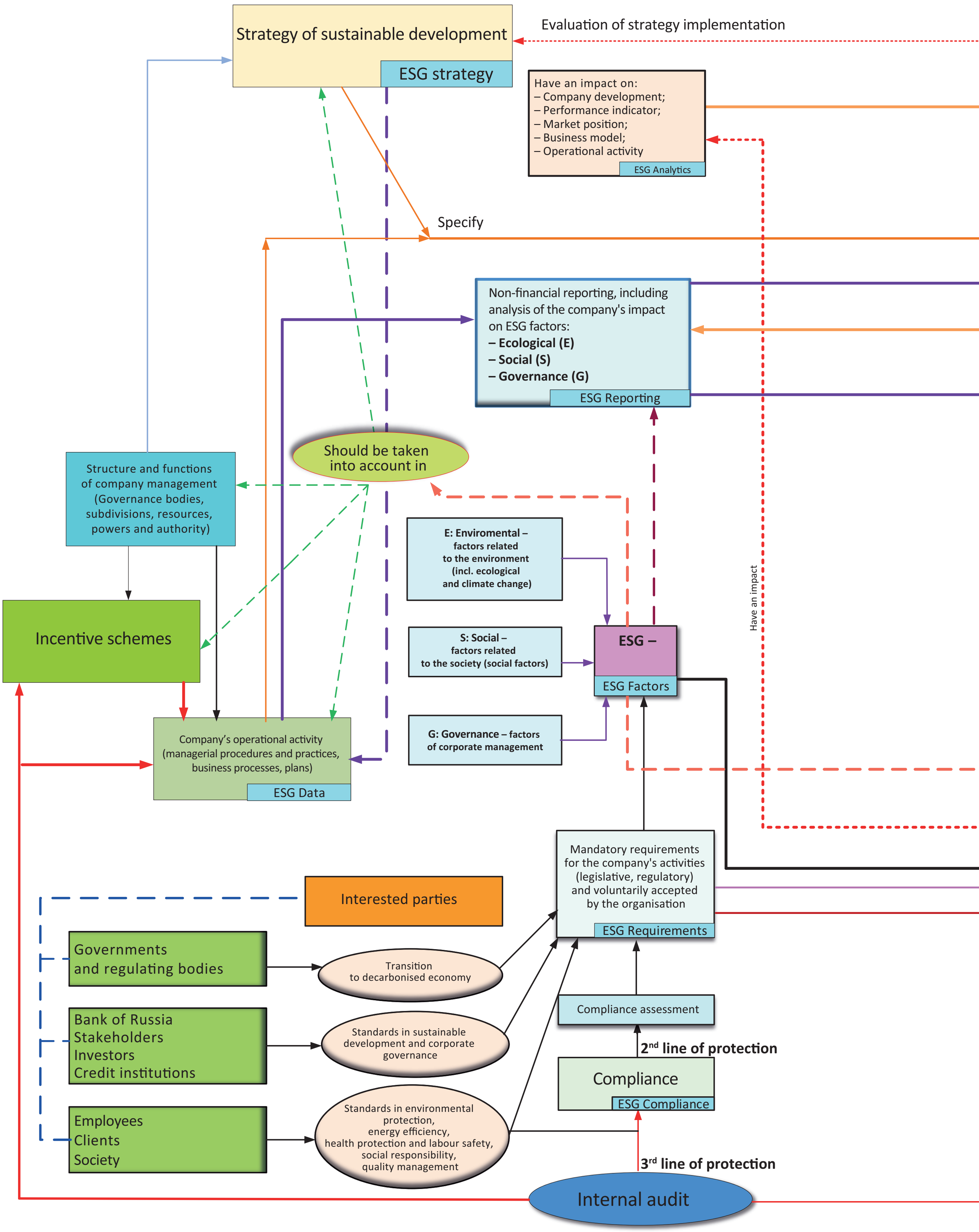
Interested parties in obtaining ESG reporting are shareholders, investors, customers, partners, employees, the media, social groups, professional and scientific circles. Along with general questions, each of the stakeholders pays attention to specific aspects of ESG reporting.

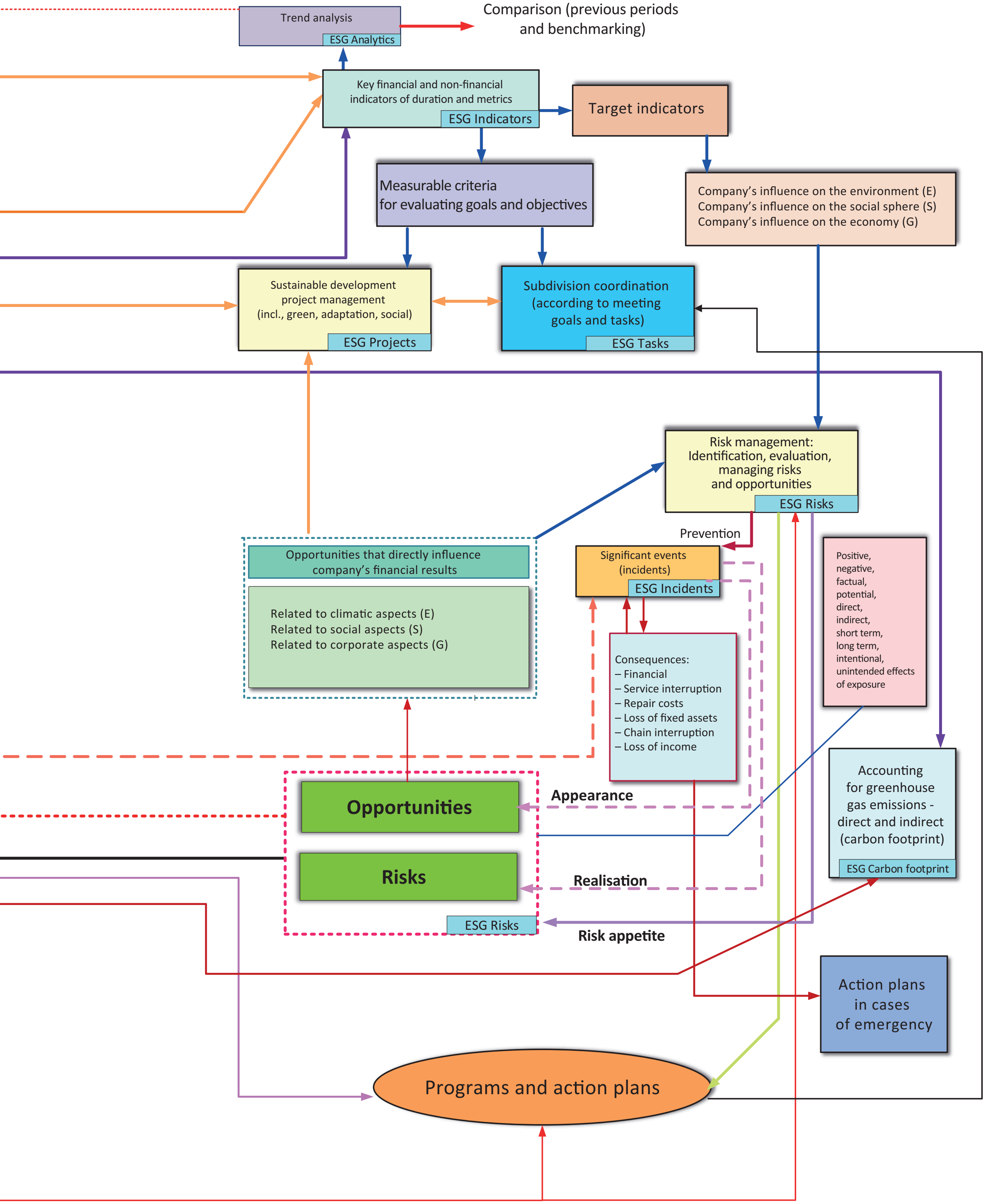
ESG reporting should disclose information on environmental, social and governance issues, compliance with regulatory requirements and legislation necessary to understand the development and the business model used.

ESG reporting should be: Substantial, Reliable, Balanced (include positive as well as negative facts), Clear, Comprehensive but concise, Forward looking, Stakeholder oriented, Consistent, Comparable and Accessible (one click maximum).

ESG reporting allows you to more reasonably formulate a strategy, monitor and manage ESG risks based on a broad dialogue with stakeholders, and strengthen social reputation [Practical recommendations.., 2021].

Non-financial reporting should show, on the one hand, Organizational sustainability conceptual model




Trend analysis
ESG Analytics
Comparison (previous periods and benchmarking)
Key financial and non-financial indicators of duration and metrics
ESG Indicators
Target indicators
Measurable criteria for evaluating goals and objectives
Company's influence on the environment (E)
Company's influence on the social sphere (S)
Company's influence on the economy (G)
Sustainable development project management (incl., green, adaptation, social)
ESG Projects
Subdivision coordination (according to meeting goals and tasks)
ESG Tasks
Risk management: Identification, evaluation, managing risks and opportunities
ESG Risks
Prevention
Opportunities that directly influence company's financial results
Related to climatic aspects (E)
Related to social aspects (S)
Related to corporate aspects (G)
Significant events (incidents)
ESG Incidents
Consequences:
– Financial
– Service interruption
– Repair costs
– Loss of fixed assets
– Chain interruption
– Loss of income
Positive, negative, factual, potential, direct, indirect, short term, long term, intentional, unintended effects of exposure
Accounting for greenhouse gas emissions - direct and indirect (carbon footprint)
ESG Carbon footprint
Opportunities
Appearance
Risks
Realisation
ESG Risks
Risk appetite
Action plans in cases of emergency
Programs and action plans

the extent of the organisation's impact on the environment (including the climate), the social sphere (including the observance of human rights) and the economy; on the other hand, how the organisation takes into account the impact of ESG factors and associated risks and opportunities on the organisation's performance, its development and market position [Bank of Russia Information Letter No. IN-06-28/49.., 2021].

When setting up an ESG reporting system, you can be guided by the recommendations of the World Business Council for Sustainable Development (WBCD), methods of rating agencies and regulatory standards (decrees of the Government of the Russian Federation, recommendations of the Bank of Russia, SASB, GRESB, CDP, GRI, EU Taxonomy Regulation, etc.).

This process will be greatly facilitated by automated systems that generate reports using predefined templates that include relevant ESG data and information. Collecting and presenting ESG data to internal and external stakeholders can be done using a library of generic and custom ESG metrics and built-in analytics. It will be useful for corporate governance bodies and stakeholders to visualise the impact of ESG factors on the management system, strategy, risk management, results achieved and the system of indicators used.

12. Working with suppliers and accounting for direct and indirect greenhouse gas emissions (carbon footprint)

It is necessary to organise a record of the suppliers (contractors, performers) involved in the supply chain in the context of the company's products (services) with the identification of the ESG risks and opportunities associated with them.

It is recommended to evaluate the sustainability practices and ESG of partners, suppliers and sub-suppliers (including from the point of view of their potential harm to the environment, including their carbon footprint) and plan actions to eliminate the risk they pose to the company. Mechanisms should be implemented to account for greenhouse gas emissions - direct and indirect, for calculating the carbon footprint both for the company as a whole and for the products (services) produced by the company along the entire supply chain.

4. Visualisation of the conceptual model of sustainable development

For a better understanding of the conceptual model of sustainable development, it is necessary not only to give a list of its structural elements with their brief description, as was done above, but also to display the relationship and interaction between these elements. Thus, we get a visual representation of the conceptual model of sustainable development of the organisation (see Figure).

Let it be hoped that the model presented by the author will help companies understand and structure their activities in the areas of sustainable development and ESG, organise joint work of staff and manage ESG data, generate reports and share their success in the field of sustainable development with stakeholders. The next step is to build an integrated platform for managing sustainable development and ESG in order to quickly take into account the impact of ESG factors on the results of the company's financial and economic activities, as well as the impact that the company's activities have on the environment, social sphere and economy.

References

Vysokov V.V. (2021). *Flexible digitalization of ESG banking: A scientific and practical guide*. Rostov-on-Don, Rostov State University of Economics. (In Russ.)

Information letter of the Central Bank of the Russian Federation No. IN-06-28/49 dated July 12, 2021 "On recommendations for public joint-stock companies to disclose non-financial information related to the activities of such companies" (2021). (In Russ.)

Information letter of the Central Bank of the Russian Federation No. IN-06-28/96 dated December 15, 2021 "On recommendations for the board of directors (BoD) of a public joint-stock company to take into account ESG factors, as well as sustainable development issues" (2021). (In Russ.)

Decree of the Government of the Russian Federation dated September 21, 2021 No. 1587 "On Approval of Criteria for Sustainable (including Green) Development Projects in the Russian Federation and Requirements for the System for Verification of Sustainable (including Green) Development Projects in the Russian Federation" (2021). http://static.government.ru/media/files/3hAvrl8rMjp19BApLG2cchmt35YBPH8z.pdf. (In Russ.)

Practical recommendations of the banking community on the implementation of ESG banking in Russia (2021). https://asros.ru/upload/iblock/160/PRAKTICHESKIE-REKOMENDATSII-BANKOVSKOGO-SOOBSHCHESTVA-PO-VNEDRENIYU-ESG_BANKINGA-V-ROSSII.pdf. (In Russ.)

Order of the Federal Agency for Technical Regulation and Metrology dated April 5, 2022 No. 866 "On organizing the activities of the Standardization Technical Committee 'Sustainable Development'" (2022). https://law.tks.ru/document/705923. (In Russ.)

Decree of the Government of the Russian Federation dated July 14, 2021 No. 1912-r "On approval of the goals and main directions of Sustainable (including green) Development of the Russian Federation" (2021). https://legalacts.ru/doc/rasporjazhenie-pravitelstva-rf-ot-14072021-n-1912-r-ob-utverzhdenii/. (In Russ.)

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Digital transformation strategy: Assessment of digital maturity of the Russian electric power industry

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Abstract

Based on the analysis of domestic and foreign experience of digital transformation and the conducted expert survey, the authors conclude that Russia, in comparison with other countries, does not have a leading position in the implementation of digital technologies. At the same time, the electric power industry being the basic sector of the economy which is responsible for its safe and sustainable development, in terms of digitalization is on the sidelines, yielding to retail, the banking industry, telecommunications and the manufacturing industry. At the same time, digitalisation is a promising direction and can have a significant positive impact on the electric power industry. The purpose of the study is to assess the current level of digital maturity of the electric power industry in Russia, identify the main barriers to digital transformation and develop proposals in order to overcome them.

The article uses generalisation, comparative analysis, analyses empirical data of digitalisation in Russia and abroad, conducts a survey of experts in the electric power industry about its digital maturity.

Keywords: electric power industry, digital transformation.

For citation:

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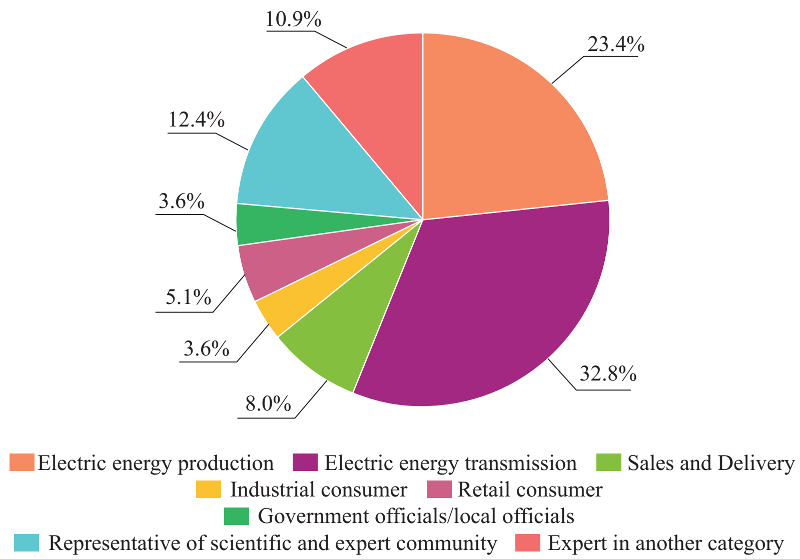
Introduction

Digitalisation in modern conditions is becoming one of the priority areas for the development of companies and states. So, in 2021, approximately 56% of CEOs around the world planned to increase the share of digital technology use[1]. And a number of countries, such as Germany and the UK, have already achieved significant results in digital transformation [International Digital Experience.., 2020].

In Russia, digital transformation in 2020 is defined as one of the national development goals[2]. At the same time, the internal costs of domestic organisations for the creation, distribution and use of digital technologies and related products and services in 2020 increased by 15.8% compared to the pre-Covid 2018 [Tsifrovaya ekonomika.., 2022]. To what extent such growth is explained by closer attention to this issue on the part of the state is a separate issue. An expert assessment of such an impact will be presented below.

[1] Priorities for IT technology initiatives 2020–2021. https:// www.statista.com/statistics/1106032/top-priorities-it-technology-initia- tives.
[2] Decree of the President of the Russian Federation of July 21, 2020 No. 474 "On the national development goals of the Russian Federation for the period up to 2030".

Fig. 1. Respondents' sphere of activity (%)



It seems that the understanding of the companies themselves had a greater effect, that digital transformation has become a necessary condition for maintaining competitiveness and the key to their development in the long term.

At the same time, the level of use of digital technologies by Russian companies is generally inferior to foreign competitors - the pace of implementation of individual digital initiatives is 5–10 years behind [Digital transformation of industries.., 2021]. Although there are pleasant exceptions, for example, Yandex, Mail.Ru, Tinkoff, Sberbank, 1C, Rostelecom, some of which can even compete with international companies both in the domestic and foreign markets.

As for the electric power industry, it came to digitalisation much later. It is only increasing its potential, yielding to industries that already use a large number of solutions, such as retail, banking, telecommunicationsand manufacturing. It should be understood that in such an area as digitalisation, one can very quickly become a leading industry from a lagging one, especially when using the positive and taking into account the negative experience accumulated by other industries.

The introduction and development of digital technologies in the electric power industry is usually associated with the possibility of companies reaching a new scientific, technological and industrial level, increasing the stability of the energy system as a whole and ensuring the accelerated implementation of the main economic trends in electrification, decarbonisation and decentralisation.

Some experts estimate the potential growth in revenues of energy companies from digital transformation only in the short term by 3-4% per year [Khitrykh, 2021].

In order to build an effective digital transformation strategy for the electric power industry, it is important to understand the current level of its digital maturity, the main obstacles that companies face when implementing digital solutions, and their readiness for digital transformation.

1. Research methodology

In order to assess the digital maturity of the electric power industry in Russia, the main barriers that companies face when implementing digital solutions and readiness for digital transformation, an expert survey was conducted in April-May 2022, in which 135 respondents took part (anonymously). The characteristic of respondents is presented on Fig. 1 and 2. An important criterion for selecting respondents was expertise and/or experience in the electricity industry. For the correct interpretation of the results, empty answers were excluded from the number of answers.

The expert survey addressed four blocks of questions:

– the need for digitalisation of the electric power industry and the current level of digitalisation;
– key advantages and prospects of digitalisation in the electric power industry;
– internal and external barriers that impede digitalisation;
– readiness of domestic electric power companies for digitalisation.

Fig. 2. Respondent's position in the company (%)

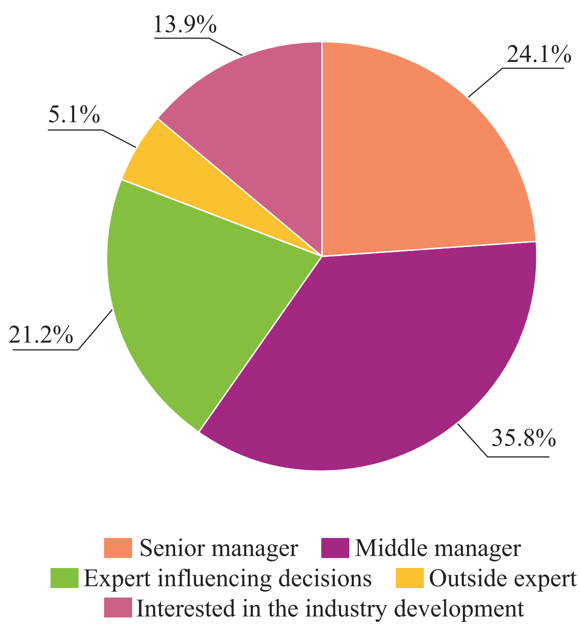
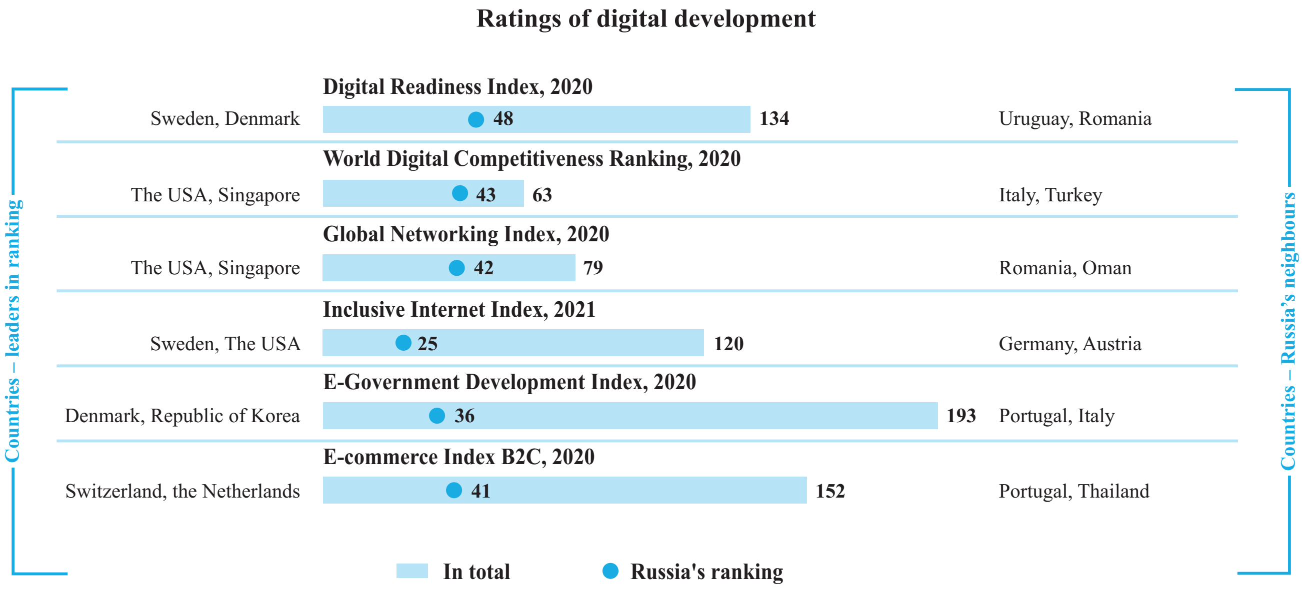


Fig. 3. Russia's position in international ratings of digital development



Source: [Digital Economy Indicators.., 2021].

The study will be useful for company owners and managers at various levels - both those already implementing digitalisation and / or digital transformation projects, and those who are just making a decision on the implementation of such projects.

2. The level of digitalisation in Russia compared to other countries

According to most indicators of the consolidated Digital Development Ranking prepared by the National Research University Higher School of Economics [Indicators of the Digital Economy.., 2021], Russia occupies an average position (Fig. 3). The main indicators of this rating included:

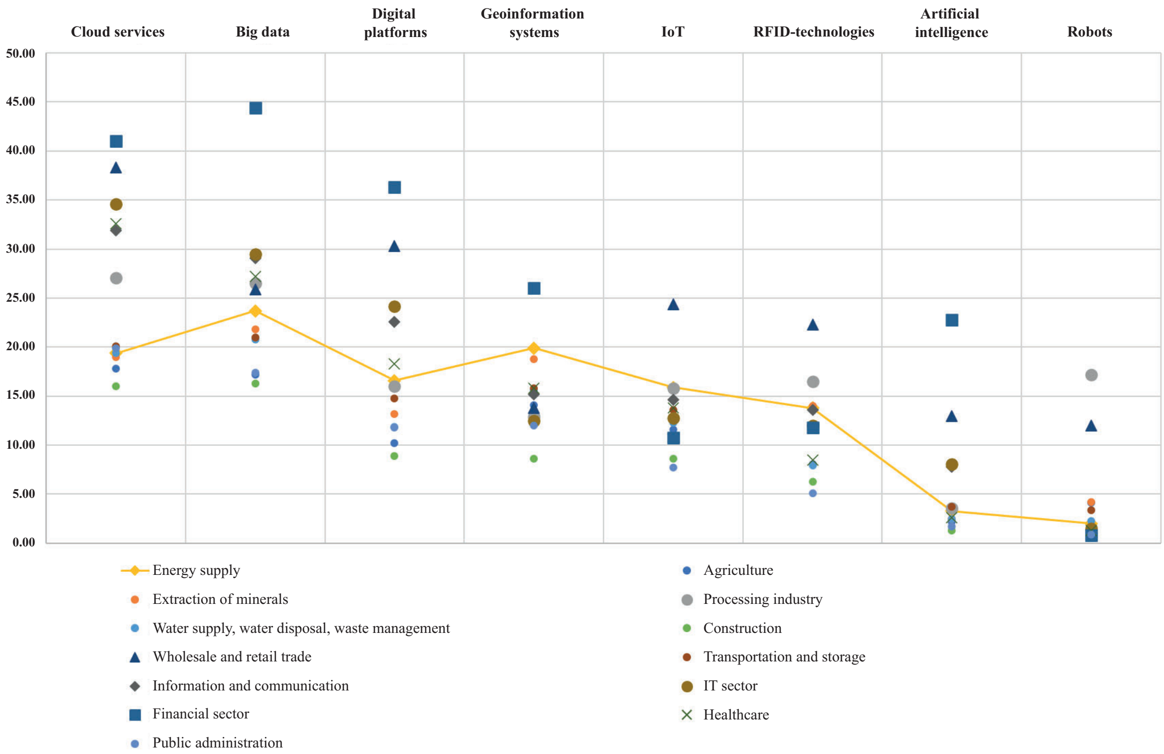
- Index of Readiness for the Networked Society[3] (Institute Portolans, 2020), which reflects the level of progress of digital technologies and their impact on the economic development of countries;
- The World Digital Competitiveness Ranking[4] (International Institute for Management Development, 2020), which allows to assess the intensity of the development and application of digital technologies by the country, leading to the transformation of public administration, business models and society as a whole;
- Global Networking Index[5] (Huawei, 2020), which characterises the relationship between the level of digitalisation in a country and economic growth;
- The Inclusive Internet Index[6] (analytical department of The Economist, 2021), characterising the degree of Internet penetration in 100 countries;
- E-Government Development Index (United Nations Department of Economic and Social Affairs, 2020), reflecting the readiness of countries to implement e-government services [E-Government survey.., 2020];
- B2C e-commerce index (UN Conference on Trade and Development, UNCTAD, 2020), which characterises the ability of countries to conduct e-commerce in business for the consumer [The UNCTAD B2C.., 2020].

Of particular interest are data on the effectiveness of research and development in the field of information and communication technologies (ICT), reflecting the country's potential in this area and independence from imported technologies, as well as its promising place in the world market.

So, in 2020, the number of publications of Russian authors in the field of ICT in scientific journals indexed in Scopus amounted to about 18.4 thousand (or 3.44% of the global number of publications in the field of ICT) [Digital economy.., 2022]. According to this indicator, Russia is among the top ten countries and takes an honorable 8th place [Indicators of the digital economy.., 2021]. At the same time, the number of publications of the leaders of the rating is as follows: China - more than 120 thousand, the USA - about 72 thousand and India - about 44 thousand

[3] The network readiness index 2020: Accelerating digital transformation in a post-COVID global economy. https://enterprise.press/wp-content/uploads/2020/11/NRI-2020-Final-Report.pdf.
[4] World Digital Competitiveness Ranking. https://www.imd.org/wcc/world-competitivenesscenter-rankings/world-digital-competitiveness-rankings-2020/.
[5] Shaping the New Normal with Intelligent Connectivity. https://www.huawei.com/minisite/gci/assets/files/gci_2020_whitepaper_en.pdf?v=20201217v2.
[6] The Inclusive Internet Index. https://theinclusiveinternet.eiu.com/explore/countries/performance.

Fig. 4. Use of digital technologies in organisations by type of economic activity, 2020 (% of the total number of organisations)



Source: compiled by the authors after [Digital economy.., 2022].

publications. In terms of patent applications for inventions in the field of ICT, Russia is already in the second ten countries with an indicator of 2.4 thousand (or 0.29% of the global number of patent applications for inventions in the field of ICT). It is significantly behind such leaders as China with more than 346 thousand applications, the USA - more than 154 thousand and Japan - more than 105 thousand applications.

Having considered the position of the energy industry in the use of digital technologies in comparison with other industries in Russia, it can be stated that the energy industry does not belong to the list of leading industries for this indicator (Fig. 4), yielding to such sectors of the economy as industrial production, wholesale and retail trade, the information technology industry and the financial sector.

Analysing the indicators of "green digitalisation" [Turovets et al., 2021] (the share of smart meters in the total number of meters and the share of electric vehicles in the total number of cars in the country) in different countries,

Table 1
Indicators of "Green Digitalization"

Indicator	China	The USA	India	Russia	Japan	Canada	Germany	France	Spain
Share of smart meters in the total number of meters (%)	99 (2018)	57	1 (2019)	10 (2018)	67 (2018)	80 (2019)	15	22.2 (2018)	93.1 (2018)
Share of electric vehicles in the total number of vehicles in the country (%)	0.94 (2018)	1.9 (2019)	0.3 (2019)	0.014 (2020)	1 (2019)	0.14 (2019)	2.96	2.7	1.31
Average power cut duration (min.)	—	348 (2018)	317 (2018)	120 (2019)	21	—	—	—	—
Average share of electricity losses (%)	5.8 (2019)	5	33	11 (2019)	4	9	4.46 (2018)	6.41 (2018)	8.93 (2018)
Number of filling stations with charging function electric vehicles (pcs.)	80 800 (2019)	26 000 (2019)	250 (2019)	1 612 (2019)	7 900 (2019)	5 000 (2019)	27 459 (2019)	24 950 (2019)	5 209 (2019)

Fig. 5. Estimates of digitalisation level of the electric power industry in Russia (% of respondents)

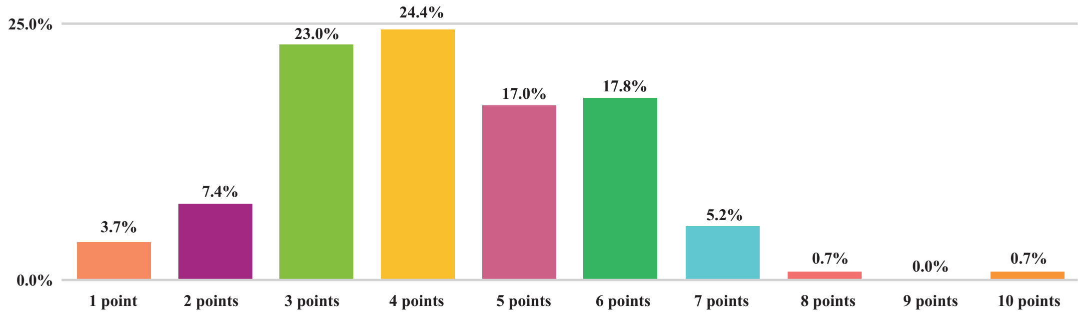
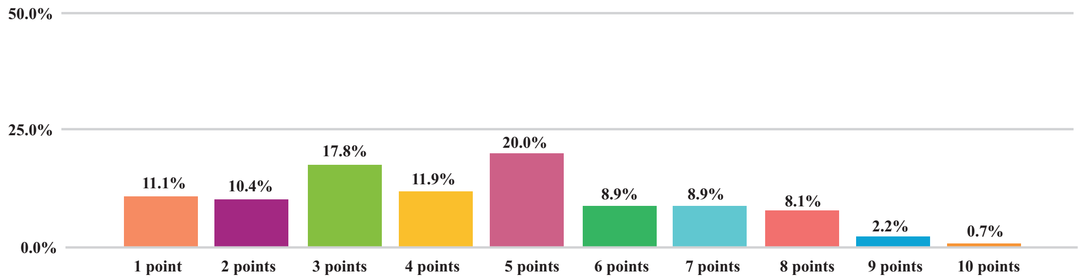


Fig. 6. Estimates of digitalisation level of companies (% of respondents)

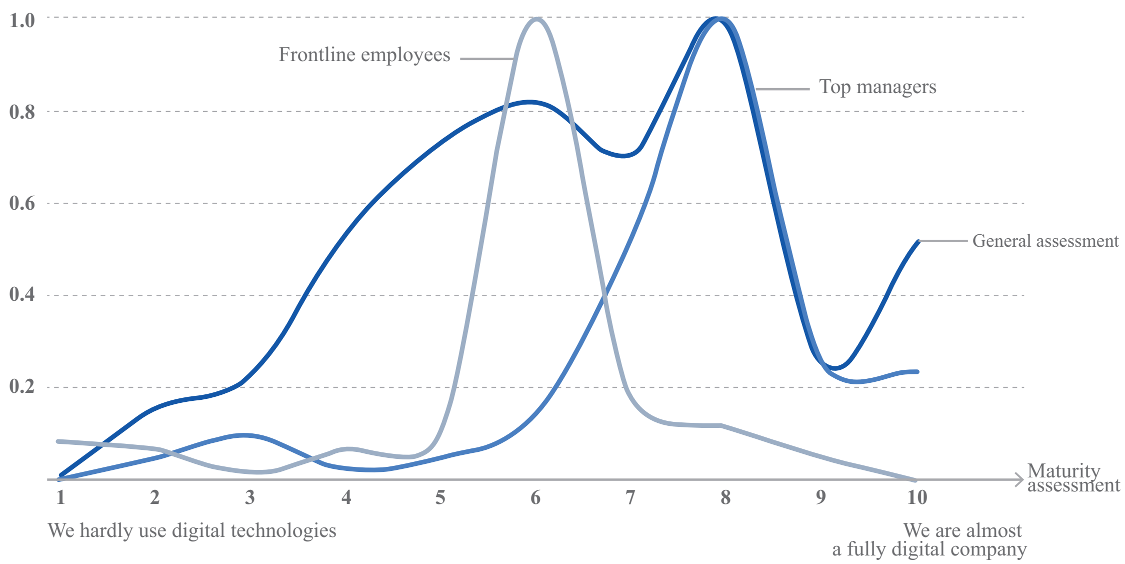


it can be seen that the share of smart meters in Russia and the share of electric vehicles in the total the number of cars is very small – 10% and 0.014%, respectively (for comparison: 99% and 0.94%, respectively, in China) (Table 1). Compared to India and the USA, Russia has a good level of uninterrupted power supply - the average duration of a power outage is 120 minutes. The level of losses is quite high - 11%. Infrastructure for electric vehicles is not enough: 1,612 gas stations in Russia compared to 80,800 in China or 26,000 in the USA.

3. Survey results

At the same time, estimates of the digitalisation level in the electric power industry in Russia are insignificant, but differ by sector. Thus, representatives of the sphere of energy sales activities assess the level of digitalisation at an average of 4.6 out of 10 points, the production of electrical energy - by 4.16, and the transmission of electrical energy - by 3.6 points. Some of the most optimistic estimates of the digitalization level in the electric power industry were received from officials - 5.2.

Fig. 7. Assessment of the digital maturity of industrial enterprises by top managers and frontline employees



Source: [Digital transformation in Russia.., 2020].

Fig. 8. Digitalisation stage in the company (% of respondents)

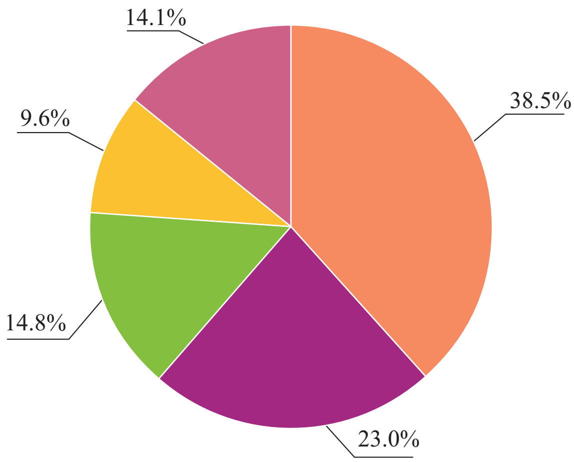
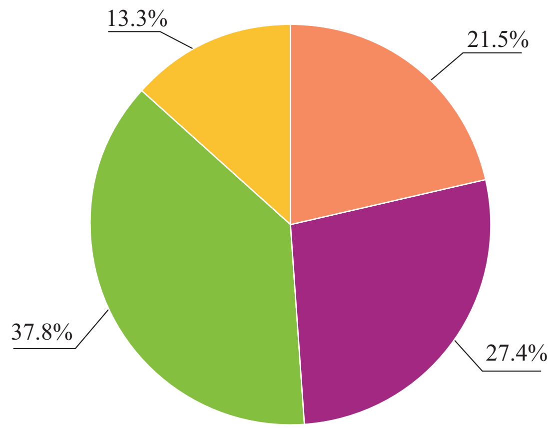


Fig. 9. The level of company team formation for the digitalisation process (% of respondents)



The average level of assessment of the digitalisation of their company by survey participants was 4.41 points out of 10, which indicates a low level of digitalisation of Russian electric power companies. The majority of respondents (20%) rated the level of digitalisation in their company as 5 points out of 10 (Fig. 6).

Interestingly, in the KMDA study [Digital transformation in Russia.., 2020], there was a rather serious gap between the perception of digital maturity on the part of top managers and ordinary employees (Fig. 7). The following factors were attributed to the reasons for this gap: earlier transformations at the top management level, reassessment of the actual level of digitalisation by top management, top management's lack of all information about problems on the ground (bunker effect), insufficient awareness of ordinary employees about the strategy , projects and plans for digital transformation.

For the electric power industry, such a gap is either practically not observed, or it has a diametrically opposite character. Thus, for the electricity generation sector, top managers rate the level of digitalisation of their company at 3.1 points out of 10, while middle managers and experts - at 5 points. Senior managers in companies engaged in the transmission of electric energy rate the level of digitalisation of their company at an average of 3 points, and middle

Table 2
Positive effects of the digitalisation in the electric power industry and the extent of their impact (% of respondents)

Positive effects	% of votes	Degree of impact		
		low	average	high
Increasing the level of process transparency	100	7	25	67
Improving the quality of mode control, optimising the load at power plants	96	3	28	68
Reduced equipment maintenance costs	96	38	40	22
Improved performance and security	94	15	46	39
Reducing the time of connections to power plants	93	44	37	19
Improving the reliability and stability of the power system	92	13	43	44
Identification of non-contractual and unmetered consumption	91	14	36	50
Improving customer experience	91	22	38	40
Improving consumption efficiency	90	18	42	40
Sustaining the environment and reducing CO_2 emissions	90	49	34	17
Accelerating the development of the electricity market	88	26	39	34
Reducing the final price of electricity	88	56	33	11

Fig. 10. The most promising technologies for the implementation and development of the electric power industry (% of respondents)

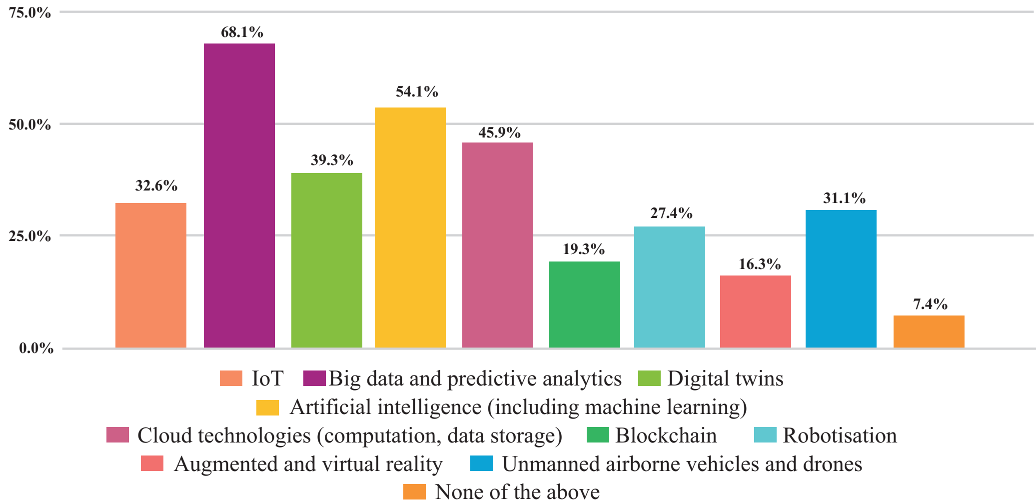
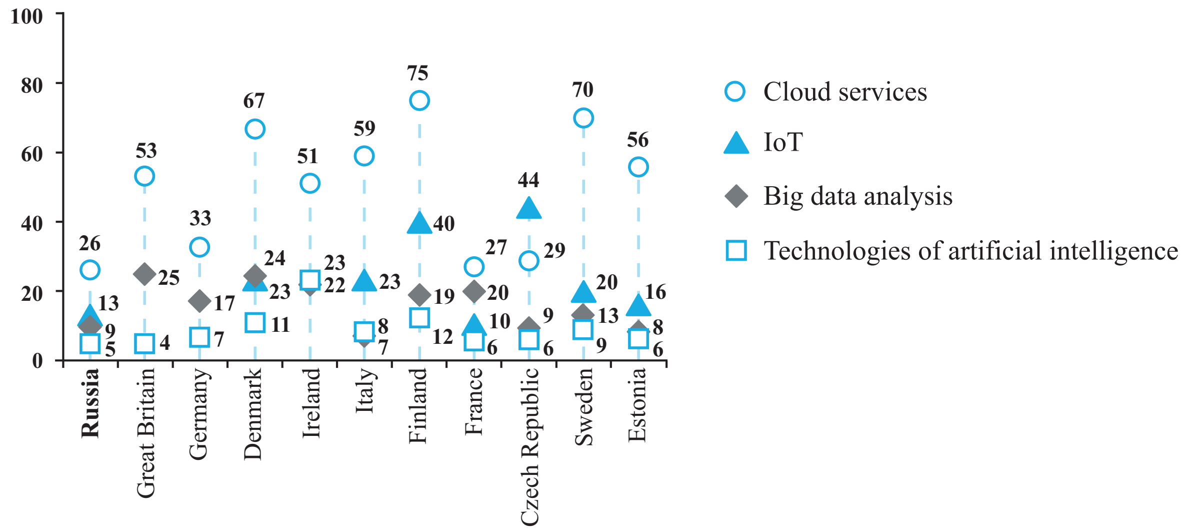


Fig. 11. Application of digital solutions in companies by country
(% of the total number of companies)



Source: [Digital economy.., 2022].

Table 3
External barriers to digitalisation (% of respondents)

External barriers	% of votes	Degree of impact		
		low	average	high
Sanctions and lack of own innovative solutions	93	14	29	56
Imperfection of the legal and regulatory framework	93	17	43	40
Presence of digital inequality of the population and technological limitations	90	30	33	38

Table 4
Internal barriers to digitalization (% of respondents)

Internal barriers	% of votes	Degree of impact		
		low	average	high
Lack of staff competencies and experience in the practical implementation of new technologies	99	8	29	63
Depreciation and obsolescence of the infrastructure of existing assets	96	7	25	68
Wary attitude to everything new and lack of understanding of the need	96	22	42	36
Lack of investment and funding	95	6	27	66
Non-recoupment of projects	93	8	41	51
Lack of cooperation in the company on digitalisation issues	91	8	46	46

managers and experts at 3.7 points. In sales companies, the average rating of top managers corresponds to 5.3 points, middle managers and experts - 5.6 points.

The results of the survey of respondents regarding the stage of digitalisation at which their company is located also confirmed previous data on the low level of digitalisation of electric power companies. 39% of respondents (52 out of 135) indicated that their companies are at the initial stage of digitalisation, 23% - at the middle stage, and only 15% believe that their companies are at an advanced level of digitalisation (Fig. 8). At the same time, the initial stage of digitalisation was understood as the position of the company, when only the processes of interaction with partners and customers are digitalised in it; middle stage - supporting processes (HR, marketing, finance) are digitalised; advanced stage - product creation and key processes are digitalised.

Looking at the sectors, 60% of the surveyed representatives of grid companies, 32% of representatives of generating companies and 27% of representatives of supply companies believe that their companies are at the initial stage of digitalisation.

Only 22% of respondents (29 out of 135) said that teams responsible for digitalisation processes have been formed and coordinated in their company. In 65% of cases, such teams are not formed or coordinated and operate in isolation from each other (Fig. 9).

As the most significant positive effects from the digitalisation of the electric power industry, the interviewed experts identified the following: improving the quality of mode control and optimising the load at power plants - 68%, increasing the level of transparency of processes - 67%, identifying non-contractual and unmetered consumption - 50%, increasing the reliability and stability of the power system - 44%, improvement of customer experience - 40% (Table 2).

The most promising technologies for implementation and development, according to respondents, are big data and predictive analytics - 68%, artificial intelligence - 54%, cloud technologies - 46% and digital twins - 39% (Fig. 10).

Fig. 12. Factors that hinder return on investment in digitalisation (% of respondents)

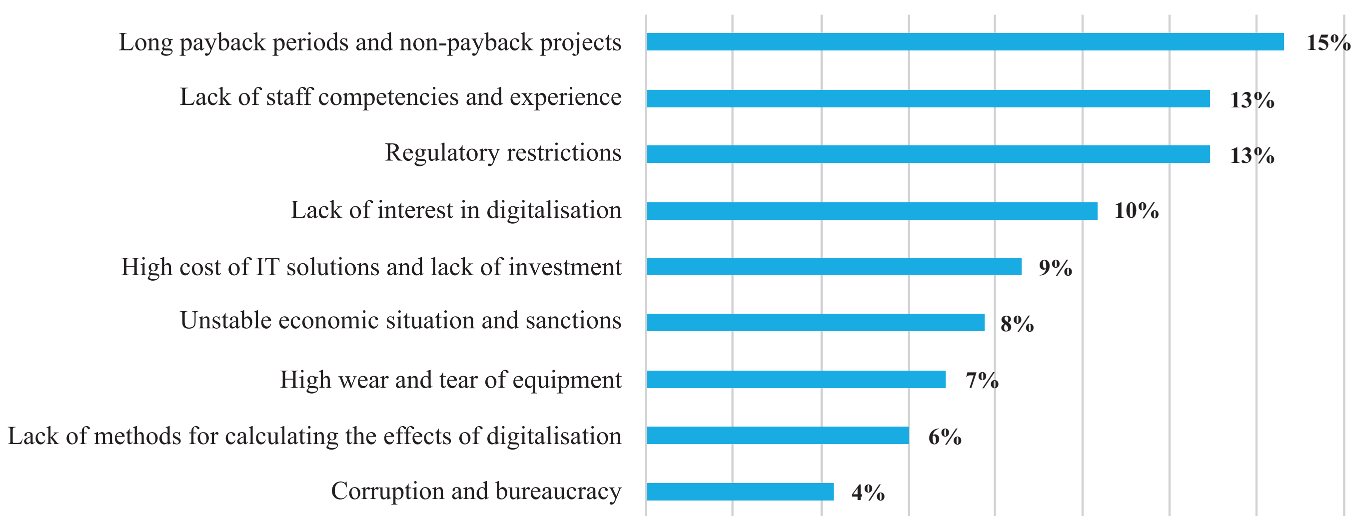
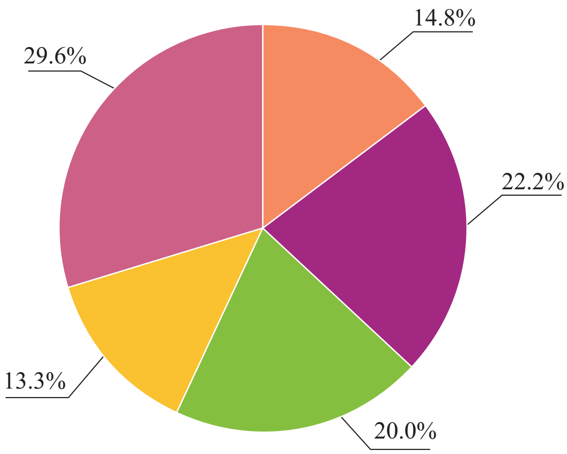


Fig. 13. The impact of the legislation of the Russian Federation in the field of digitalisation on the digital development of companies in the electric power industry (% of respondents)



When comparing the use of digital solutions in the corporate sector by country, it can be seen that Russia lags far behind developed countries in a number of areas (Fig. 11). On the one hand, this indicates a certain level of digital underdevelopment, on the other hand, it indicates that even not the largest investments of companies aimed at introducing digital technologies can bring a tangible effect, which creates serious opportunities for the development of both individual companies and the economy as a whole.

As the most significant external barriers to digitalisation, experts identify the sanctions imposed on Russia and the lack of their own innovative solutions - 56%, the imperfection of the legal and regulatory framework - 40%, the presence of a digital inequality of the population and technological restrictions - 38% (Table 3).

Among the most significant internal barriers to digitalisation, experts attributed the deterioration and obsolescence of the infrastructure of existing assets by 68% of respondents, the lack of competencies among staff and practical experience in implementing new technologies - 63%, lack of investment and financing - 66% and the failure to pay back projects - 51% (Table 4).

The most significant factors hindering the return on investment in digitalisation were named by experts as long payback periods or non-payback projects - 15%, lack of staff competencies and practical experience in implementing new technologies - 13%, regulatory restrictions and policy of curbing tariff growth - 13%, lack of interest - management in digitalisation due to the lack of economic incentives to improve efficiency - 10% (Fig. 12).

According to respondents, the return on investment is affected by the lack of a comprehensive assessment of these investments as part of production and business chains and the difficulty of identifying a specific effect from digitalisation, low investment activity, low management efficiency, and lack of understanding of the goals of digitalisation.

Among other reasons, survey participants also named: lack of a statutory return on investment mechanism, lack of direct subsidies, weak government support measures (tax rates, complex regulatory framework), weak competition in the industry and the absence of independent regulators, high cost of technologies and insufficient elaboration of projects, high added value due to intermediary companies.

Some respondents noted that the digitalisation of Russian companies is hampered by the unpreparedness of state power industry regulators to liberalise energy markets and the large-scale emergence of new types of active consumers, while the need to restrain the growth of tariffs for the end consumer, regulatory and social restrictions hinder the implementation of new approaches.

Some respondents drew attention to a serious problem in the power grid complex. Within the framework of the existing tariff regulation and the actual liquidation of small territorial grid organisations (meaning the latest legislative innovations related to the exclusion of entrepreneurial profits from small TGOs and the tightening of quantitative criteria for TGOs in order to force the consolidation of electric grid assets), investments in digitalisation are possible only from PJSC Rosseti , its subsidiaries and affiliates. The rest of the TGOs are only interested in survival.

Fig. 14. The impact of mandatory government digitalisation programs on electric utilities (% of respondents)

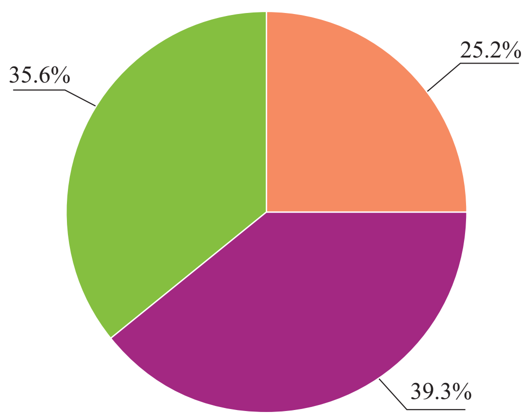
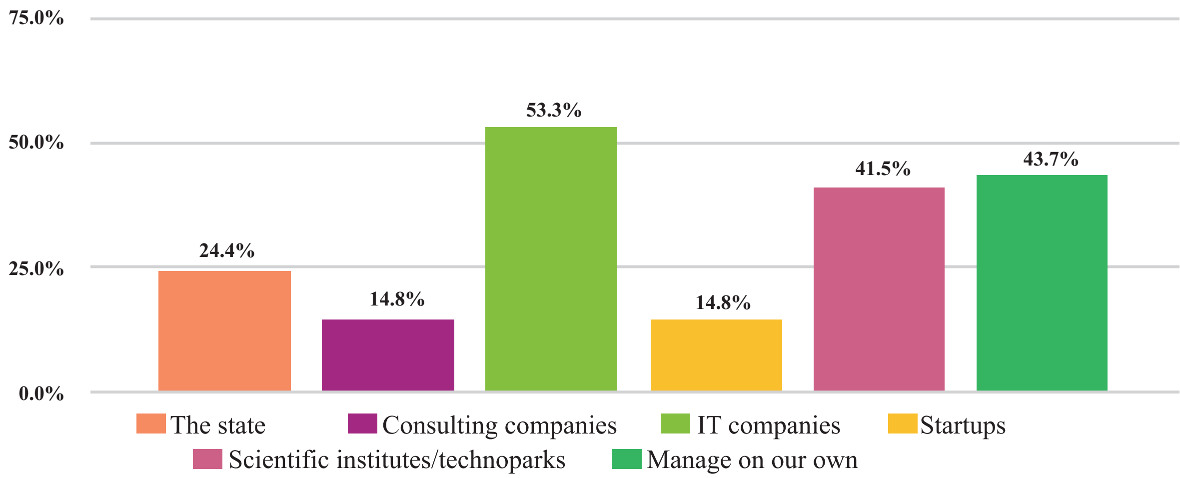


Fig. 15. Who companies rely on most for the development and implementation of digital solutions (% of respondents)



63% of respondents (85 out of 135) are sure that the lack of their own developments and import substitution will slow down the pace of digitalisation of the electric power industry. 13% believe that import substitution, on the contrary, will accelerate the pace of digitalisation of the electric power industry, and 17% are sure that import substitution will not affect the pace of digitalisation in any way.

According to 37% of survey participants (50 out of 135), digitalisation legislation is a barrier to the digital development of companies in the electric power industry (Fig. 13).

A quarter of respondents (34 out of 135) believe that the establishment of mandatory state programs for digitalization leads to a decrease in the effectiveness of measures, since companies are aimed at implementing the program "at any cost" (Fig. 14).

The majority of respondents (53%) rely on IT companies to develop and implement digital solutions, 44% do it on their own, and 42% plan to turn to research institutes/technoparks for help (Fig. 15).

Conclusion

The study of digital development level of the electric power industry allows us to formulate a number of main conclusions.

- Russia, in comparison with other countries, does not differ in leading positions in the field of digital technologies implementation and is at the average level.
- The electric power industry, being the basic sector of the economy responsible for its safe and reliable development, is in the background in terms of digitalisation, yielding to retail, the banking industry, telecommunications, and the manufacturing industry.
- The vast majority of respondents - 86% - believe that digitalisation in the electric power industry is necessary, but assess its current level as low - at 4.27 points out of 10.
- 62% of respondents believe that their companies are at the initial or middle stage of digitalisation. At the same time, in the power grid complex, 60% of respondents assess the level of digitalisation of their companies as initial.
- 65% of respondents noted that in their companies the teams responsible for digitalisation processes are not formed or coordinated and act separately from each other.

Thus, the results of the survey, as well as international indices, confirm rather low level of digitalisation of Russian electric power companies compared to foreign competitors.

At the same time, digitalisation is a promising direction and can have a significant positive impact on the electric power industry. The results of the expert survey indicate that the industry should focus on staff development, the development of innovative thinking and culture, as well as financial instruments for investing in digital technologies.

Companies, together with the state, need to eliminate or minimise the challenges that arise in the process of introducing digital technologies so that digital projects become more attractive to investors and can pay off. The development of programs for the return of investments in digitalisation and financial support for the renewal of worn-out and obsolete assets from the state will increase the interest of top management of companies in digitalisation and will make it possible to achieve payback for digital projects.

For successful digital transformation, companies need to increase the digital maturity and competence of employees, develop a corporate culture of innovation, and focus on the digitalisation experience of other leading companies.

References

Indicators of the digital economy: 2021: statistic collection (2021). Moscow, NRU HSE. (In Russ.)

International experience of digital transformation of the electric power industry (2020). Association of organizations for digital development of the industry "Digital Energy". https://www.digital-energy.ru/wp-content/uploads/2020/06/doklad-rb-1.pdf. (In Russ.)

Khitrykh D. (2021). *About digital transformation of the energy industry.* https://energypolicy.ru/o-czifrovoj-transformaczii-energeticheskoj-otrasli/neft/2021/19/05/.(In Russ.)

Digital transformation in Russia-2020: Overview and recipes for success (2020). https://drive.google.com/file/d/1xVK4lSanDZSCN6kGAHXikrGoKgpVlcwN/view. (In Russ.)

Digital transformation of industries: starting conditions and priorities (2021). Moscow, NRU HSE. (In Russ.)

Digital economy: 2022: A short statistical collection (2022). Moscow, NRU HSE. (In Russ.)

E-government survey 2020. Digital government in the decade of action for sustainable development (2020). New York, United Nations. https://publicadministration.un.org/egovkb/Portals/egovkb/Documents/un/2020-Survey/2020%20UN%20E-Government%20Survey%20(Full%20Report).pdf.

The UNCTAD B2C E-commerce Index 2020 spotlight on Latin America and the Caribbean (2020). UNCTAD technical notes on ICT for development No 17, No 15. https://unctad.org/system/files/official-document/tn_unctad_ict4d17_en.pdf.

Turovets J., Proskuryakova L., Starodubtseva A., Bianco V. (2021). Green digitalization in the electric power industry. *Foresight and STI Governance,* 15(3): 35-51.

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Using digital platforms for strategic development of industrial companies

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Abstract

Digital platforms significantly transform the activities of industrial companies opening up wide opportunities for increasing labor productivity in the organization and the level of cooperation between various companies in creating value for the consumer, including innovations, entering new markets among which are also foreign ones. At the same time, the level of use of digital platforms for the designated purposes varies. This article will consider the advantages of using digital platforms for enterprises, and also determine the level of use of digital platforms for the purposes outlined above among Russian industrial companies.

Keywords: digital platforms, cooperation, digital transformation, end-to-end technologies, labor productivity, industrial companies.

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Introduction

The formation of a platform economy is one of the key results of the introduction of digital technologies that are transforming the traditional market model. Companies based on digital technologies, including digital platforms, demonstrate significantly greater productivity. Thanks to this, such organisations can grow exponentially, successfully adapt to external conditions, capturing new markets [Exponential Thinking.., 2021].

According to one of the definitions, a digital platform is "a system of algorithmic mutually beneficial relationships between a significant number of independent participants in an economic sector (or field of activity) carried out in a single information environment, leading to a reduction in transaction costs through the use of a package of digital technologies for working with data and changing the separation system labor" [Strategy of digital transformation.., 2021].

Companies can take three approaches in relation to the use of digital platforms. The first is that an organisation deliberately refuses to use them, which may be due to the characteristics of the industry / market in which it operates. Such a strategy may be due to a small number of customers.

The second approach is characterised by the fact that the organisation uses an existing platform, ready-made solutions for its own tasks. These include, for example, the use of the platform as one of the distribution channels for products, the search for partners to solve various business problems. The advantages of this approach are that the organisation bears less risk and invests less to enter the platform compared to the third approach, when the company acts as the owner or provider of the platform, that is, it creates a platform for solving business problems based on data/information received from intelligent products, equipment capable of data exchanging.

The approach taken by a company is determined by the goals it pursues. The first section of this study identified the key benefits driving the adoption of digital platforms by industrial enterprises. The methodology of the study is given below, followed by the results obtained.

1. Key benefits of using platforms for industrial enterprises

The attractiveness of platforms for user companies is determined by the set of tasks that it allows to solve. Firstly, acting as a technological basis for performing various functions, for example, in the field of organising production, marketing activities, resource management activities, etc. Secondly, acting as an intermediary in

Table 1
Benefits from the participation of industrial companies in ecosystems created by digital platforms

Benefits from being part of the business ecosystem	Definition	Authors
New business opportunities	The digital business ecosystem provides its members with new business opportunities	[Hein et al., 2020; Cozzolino et al., 2021]
Co-creation of value	Co-creation of value, which can be accompanied by improved process efficiency through the use of best practices	[Hein et al., 2020; Silva et al., 2021; Sun, Zhang, 2021]
Increasing innovation potential	The innovative potential of the company is enhanced by the impact of other types of innovation	[Helfat, Raubitscheck, 2018; Jovanovich et al., 2021; Barile et al., 2022]
Gaining a competitive advantage	An efficient business ecosystem gives a competitive advantage to all participants and creates barriers to entry for competitors	[Sun, Zhang, 2021]
Gain access to additional resources and knowledge	Solving the problem of limited resources within one company	[Garcia et al., 2022; Suurenen et al., 2022; Ko, Amankwah-Amoah, 2022]
Cost and risk management	Business ecosystem reduces costs and risks when participants cooperate to develop the innovations and solutions the business needs	[Greve, Song, 2017; Garcia et al., 2022; Suurenen et al., 2022]
Provides modularity to meet customer needs	Modularity gives more options to meet customer needs	[Jose, Tollenaere, 2005; Sun, Zhang, 2021]

the market, reducing transaction costs, simplifying the interaction between various market participants [Schreieck et al., 2016]. In this regard, digital platforms become the basis for the formation of ecosystems, the benefits of participating in which are reflected in Table 1.

At the same time, there are a number of criteria that determine the readiness of enterprises to participate in the digital platform or implement it in their activities. These include, in addition to the functionality of the platform and a set of critical mass, a number of important components:

- work on the platform of major players in the target market for an enterprise;
- geographical coverage exceeding the territory of one region/country;
- the number of participants who initiated the work of the platform and the status of these participants;
- reliability and security of the platform.

A study conducted at the Financial University in 2022, which was devoted to the study of the effects, stimulating the technological development of industry, including through digitalisation, showed that, despite the widespread discussion of the benefits that companies receive as a result of the use of digital platforms, openness issues are an important limitation of their use and integration opportunities [Scenario modeling.., 2022].

The reasons for this limitation are related to the fact that in many large industrial enterprises the process of automation was gradual, as a result of which programs are often used that may be incompatible with each other, the data collected on the equipment is heterogeneous, which leads to difficulties in their consolidation and processing. As a result, the implementation of platforms in enterprises is slow, gradually affecting the processes of different levels, the speed of implementation of platforms can also be different even within enterprises of the same holding. In this regard, the compatibility of the platform with the software of various providers is one of the conditions for accelerating the adoption of digital platforms.

Another factor important for using the platform is to ensure the safety of data and their confidentiality. Despite the fact that in a platform economy, competitors can also be considered as partners in creating value, representatives

Table 2
Characteristics of enterprises to determine the propensity to adopt platforms

Mature companies	Developing companies
The organisation has specialised divisions/departments dealing with asset management (e.g. procurement)	Unstructured and limited resources requiring cross-functional roles to manage multiple processes and activities
Standardised business processes and activities	Non-standardised business processes
Strong position in the market	An unstable position in the market, as a result of which the organisation seeks to diversify
Established network of suppliers and customers. There is a network of partners with whom the company is ready to conclude an agreement in case of a need for resources	Supplier and customer networks are under development
The selection of a supplier takes place in accordance with predetermined criteria and procedures	Supplier selection is largely based on project specific criteria (e.g. expertise, product specification).
The organisation has strategic partners with whom cooperation has been established	May have strategic partners, but mostly contracts for a specific project.
The company has effective communication channels (for example, IT systems) with suppliers/clients/partners	Limited resources to invest in efficient communication channels.
The organisation ensures information security of data using internal resources	Limited resources for solving business security problems and a large need for external service providers.

Источник: [Arica, Oliveira, 2019].

of Russian companies in the study noted a lack of trust and unwillingness to exchange data for the joint development of products and innovations.

At the same time, some authors note that the companies' own characteristics also play an important role for the participation of industrial companies in the ecosystems created by platforms. For example, the authors [Arica, Oliveira, 2019], based on the analysis of 34 companies from five European countries, identified two groups of enterprises characterised by different propensity to adopt platforms used for asset exchange within the sharing economy. The first group - mature enterprises - is characterised by a lower inclination to use platforms for their activities. The second group - developing enterprises - on the contrary, shows a greater willingness to implement and use platforms. A more detailed description of the groups is presented in Table 2.

At the same time, the authors of the study note that the digital platform is also designed to reduce the risks associated with the interaction of various companies. The risks that digital platforms should mitigate include:

- the risk of choosing an unscrupulous buyer/supplier, which is associated with the limited time and resources that the organisation can allocate for their search;
- lack of accurate information about the capabilities and experience of the supplier/contractor;
- limited choice/options of known suppliers for a specific need;
- lack of transparency on the part of the supplier and the risk of failure in business relationships with the client, especially in the case of unbalanced power relations, when a mature company has a significant share of the supplier's market;
- Uncertain results due to lack of previous experience with a particular partner.

At the same time, platforms have a significant potential for the development of the organisation. In 2020, Deloitte partnered with MAPI to conduct a study that included an online survey of 850 industrial executives in North America, Europe, Asia, and interviews with 30 industrial executives that revealed why organisations are still moving towards digital platforms in their activities [Smart manufacturing ecosystems.., 2020].

The results of the study showed that the two main reasons that explain the interest of industrial enterprises to enter into platform-based cooperation and form an ecosystem are the ability to increase the speed of development and launch of new products and services, as well as the ability to increase the amount of revenue received from the sale

Table 3
Characteristics of the sample of industrial companies

Characteristics of companies in the sample	Number of companies	Share of companies (%)
Ferrous and non-ferrous metallurgy	37	24
Food industry	27	17
Mechanical engineering and metalworking	25	16
Chemical and petrochemical industry	40	25
Forestry, woodworking and pulp and paper industry	11	7
Building materials industry	16	10
Company lifespan		
from 1 year to 10 years	53	34
11 years and over	104	66
Average headcount		
no more than 500 people.	50	32
501 people and more	107	68

Source: compiled by the author.

of products, services, including the provision of additional services. The third reason, important for industrial companies, is the reduction of operating costs, achieved by improving the efficiency of business processes.

The benefits obtained by foreign companies are also important for Russian companies. This study identifies four key goals for which Russian industrial companies can use digital platforms. The objectives of the study were to determine whether the use of digital platforms really makes it possible to achieve growth in the performance of enterprises, and to identify the features of their use.

2. Research methodology

The research methodology included a survey using questions divided into four blocks:

1) the use of digital platforms to stimulate the export of products of Russian industrial companies;
2) the use of digital platforms to increase labor productivity;
3) the use of digital platforms to increase the level of cooperation between Russian enterprises;
4) the use of digital platforms to integrate Russian manufacturers into global supply chains.

The period of the study: March - July 2022. The database of companies was formed according to the Ruslana database. A total of 157 companies took part in the survey. Table 3 shows the characteristics of the sample of enterprises that took part in the survey.

The experts were asked to answer questions using a Likert scale from 1 to 7, where 1 - platforms are not used, 7 - the company has a team of employees who develop / support the digital platform used to achieve the stated goals, while the digital platform is integrated into business processes, comprehensively covers the entire company.

The study determined the impact of the use of digital platforms on the resulting indicators:

- performance results (Yi1): sales proceeds;
- performance results (Yi2): breadth of the product range;
- performance results (Yi3): change in the number of outlets;
- performance results (Yi4): foreign trade turnover;
- performance results (Yi5): labor productivity;
- platform coverage dynamics (Yi6): change in the number of business partners;
- subjective perception of performance (Yi7): position relative to competitors;
- Dynamics of the quality of relations with partners (Yi8): change in the number of contracts.

Table 4
Factors of “Stimulating the export of Russian industrial products” block

Composite variable	Elements	Composite reliability	Factor load
Stimulating the export of Russian industrial products	The company uses foreign platforms to match foreign buyers	0.821	0.923
	The company uses the platform to search for firms that provide legal support when entering foreign markets		0.717
	The company uses the platform to search for firms that provide agency services when entering foreign markets		0.682
	The company uses platforms to search for information related to the specifics of the external market and its features		0.870
	The company uses digital platforms to gain access to distribution channels and select foreign marketplaces		0.813
	The company uses specialised platforms to search for information about the required export documentation		0.757
	The company uses specialised platforms to participate in export support programs		0.701

Source: compiled by the author.

Table 5
Factors of "Labor productivity improvement" block

Composite variable	Elements	Composite reliability	Factor load
Increased labour productivity	The company uses the platform to ensure the process of technical inspection and repair	0.738	0.713
	The use of the platform has reduced production losses (downtime)		0.627
	The use of the platform allowed to reduce production losses (material overrun)		0.734
	The use of the platform allowed to reduce production losses (defective products)		0.835

Source: compiled by the author.

Table 6
Factor loads of "Integration of Russian manufacturers into global supply chains" block

Composite variable	Elements	Composite reliability	Factor load
Integration of Russian manufacturers into global supply chains	The company, using the platform, increased the number of suppliers in the foreign market (as a result of integration into global production chains)	0.717	0.828
	The company, using platforms, increased the number of buyers in the foreign market		0.836
	The company, using the platform, increased the offer in terms of additional services		0.817

Source: compiled by the author.

Table 7
Factor loads of "Increasing the level of cooperation between Russian enterprises" block

Composite variable	Elements	Composite reliability	Factor load
Increasing the level of cooperation between Russian enterprises	Over the past 2-3 years, cooperation between enterprises using digital platforms has increased the share of new products in the total output	0.729	0.679
	Cooperation with the use of the platform has reduced the time to market for new/innovative products		0.821
	The company uses platforms to communicate with partners		0.717
	Increasing the transparency of business processes using the company's platform has increased its attractiveness for partners		0.734
	The company uses platforms to implement/ensure sales of personalised products		0.872
	Cooperation with the use of platforms made it possible to simplify the process of finding trustworthy partners		0.813

Source: compiled by the author.

For each resulting indicator, regression models were formed, the general view of which is presented as follows:

$$y = \beta_0 + \beta_1 \times x_1 + \ldots + \beta_n \times x_n, \quad (1)$$

where y is the resulting indicator, β_1 is the non-standardised coefficient, x_1 and x_n are independent variable indicators.

3. Statement of hypotheses

To achieve the objectives of the study, five hypotheses were put forward.

Hypothesis 1. There is a positive relationship between the use of digital platforms and the achievement of foreign economic activity results.

The internationalisation of a company is one of the conditions for the development of a company. At the same time, access to resources in other countries and a high level of competition contribute to optimising the implementation of the company's business processes, increasing the efficiency of its activities and the quality of products. The result may be an increase in the diversification of the company, an increase in the occupied market share, and the development of the existing market.

Entering foreign markets involves a number of difficulties, for example, the need to build supply chains from scratch, search for customers, the unknown brand of the company, search for partners / contractors, the need to take into account legal restrictions and regulatory features in a particular country. In this regard, industrial companies can use platforms that reduce uncertainty and offer services for analysing barriers to entry into a target foreign market, aggregate information about legal features (the need for licenses, permits, etc.), and also provide information on customs regulation , sanctions restrictions. An example of one of these platforms is the platform of the Export Center of Russia, where companies can consult on the implementation of export activities, provide training for employees and advanced training necessary for the implementation of export activities, obtain information on financial and credit support, etc.

To test the hypothesis, the factors shown in Table 4 were used.

Hypothesis 2: There are positive relationships between the use of digital platforms and increased productivity of the organisation's staff.

Productivity is one of the key elements that determine the competitiveness of an organisation. Digital platforms, increasing the transparency of the company's business processes, optimising the execution and control of production processes, auxiliary functions, contribute to increased productivity. In this regard, digital platforms can bring many advantages for Russian companies. According to some reports, today the productivity of Russian enterprises is two to three times lower than that of foreign companies, which is one of the reasons for their lagging behind in the competition.

There is a certain productivity limit, below which the enterprise is not able to engage in export activities [Simachev et al., 2022]. In this regard, we can say that the

Table 8
Use of digital platforms by Russian industrial companies (% of companies using digital platforms for a given criterion)

Criterion	Level 1	Level 2	Level 3
The platform is used to interact with other businesses	12		
The platform is used to ensure interaction within one group of enterprises			78
The platform is used to increase productivity			83
The platform is used to search for suppliers in foreign markets		46	
The platform is used to find clients in foreign markets		56	
The platform is used to receive consulting services when entering foreign markets	38		
The platform is used to access distribution channels in the foreign market		54	

Source: compiled by the author.

low level of productivity limits the company's ability to expand its export activities.

To determine the degree of achievement of goals as a result of the use of platforms that improve productivity in the enterprise, the factors from Table 5 were used.

Hypothesis 3. Digital platforms facilitate the integration of Russian manufacturers into global supply chains.

Digital platforms can be an effective tool for companies to enter the international market. According to [Cozzolino et al., 2021], one of the main reasons for producers to participate in digital platforms is access to advanced technologies and solutions that make it easier to distribute their products. This is facilitated by the simplification of the search for customers and partners in the global market, and the reduction of transaction costs. In this regard, it has been suggested that digital platforms can increase the integration of Russian manufacturers into global supply chains. The factors that characterise this block are presented in Table. 6.

Today, the platformisation of the economy and the formation of platform-based ecosystems are intensifying both competition and cooperation between companies [Cozzolino et al., 2021]. For example, open innovation platforms are seen as a new generation of co-creation spaces that allow participants in the innovation ecosystem to interact with each other [Rho et al., 2020], which helps to increase their joint innovation potential. The result is an acceleration of the process that develops new products, bringing them to the market and increasing the number of developments.

In this regard, the following hypotheses were put forward:

Hypothesis 4. The use of digital platforms has a positive effect on increasing the share of new products.

Hypothesis 5: There is a positive relationship between the use of digital platforms and the increase in partnerships with other organisations.

To test the hypotheses for each of the blocks, control questions were developed, presented in Table 7.

4. Research results

The results of the study showed that companies that use digital platforms to enter and work in foreign markets, in most cases, showed the achievement of the goals of foreign economic activity. At the same time, it should be noted that the use of foreign sites is more preferable when operating in a foreign market than the use of our own site for product distribution.

The advantage of foreign platforms is that export platforms that allow Russia to trade in foreign markets also provide access to B2B and B2C marketplaces of the country of presence, trade support (work with claims, marketing administration, trilateral negotiations, support in processing transactions), help to ensure optimal logistics, hold year-round product exhibitions to attract more customers. Thus, Hypothesis 1 was confirmed.

The next hypothesis related to the connection of digital platforms and productivity increase is also confirmed. At the same time, exporting enterprises almost always use digital technologies that optimise production activities, which indirectly confirms that a higher level of competition stimulates productivity and the desire of the organisation to adopt digital technologies.

Hypothesis 3, which allows to assess the impact of digital platforms on increasing integration into global supply chains, was also generally confirmed. It should be noted that the impact on economic performance indicators for 2021 was assessed - the imposition of sanctions distorted the overall picture of the effectiveness of the use of platforms. According to the Russian Export Center, only due to the purchasing power in the countries of the European Union, the number of sales of products decreased by 35%. However, today there is a change in routes, the development of digital platforms and platforms that allow entering the Asian market, for example, some enterprises have attempted to deliver goods from the EU to Russia through Uzbekistan or Iran[1].

According to the results of the analysis, it was revealed that, despite the fact that for foreign industrial companies, as noted above, one of the main reasons for using digital platforms is the development of new products, including jointly with partner companies, for Russian companies hypotheses 4 and 5 were not confirmed. This leads to the conclusion that companies are more inclined to develop innovations on their own, relying on their own resources.

Based on the analysis, it was assessed for what purposes Russian companies use digital platforms to a greater extent. The results of the analysis, which reflect the percentage of use of each platform type, are presented in Table 8, where the numbers are the percentage of companies from the sample that use digital platforms according to the given criterion.

In general, according to the results of the study, we can say that the use of digital platforms among Russian industrial companies cannot be unambiguously attributed to any one level. Although many enterprises use digital platforms to enable interaction within the same group of companies, as well as to increase labor productivity, there is still a small percentage of those companies that turn to platforms for interaction with other enterprises (this does not include supplier-to-consumer" interaction), as well as to receive consulting services when entering

[1] Official website of the Export Center. https://www.exportcenter.ru/.

foreign markets. At the same time, half of the surveyed organisations use platforms to cooperate with suppliers and customers in foreign markets.

Conclusions

Digital platforms today are one of the drivers that enhance the competitiveness of industrial companies. The potential of platforms allows enterprises not only to increase productivity, but also to simplify the process of entering foreign markets. The analysis showed that the goals pursued by foreign and Russian enterprises using platforms, despite the similarity, still differ in priority. Thus, the analysis of the literature showed that foreign companies are more often focused on building ecosystems for the joint creation of innovations and products. At the same time, as shown by the results of an empirical study, Russian industrial companies are more focused on increasing productivity and ensuring interaction within one group of enterprises. Platforms are also actively used to attract customers and partners.

References

Simachev Yu.V., Fedyunina A.A., Kuzyk M.G. (2022). New contours of industrial policy. In: *Proceedings of XXIII Yasinskaya (April) International Scientific Conference on Problems of Economic and Social Development.* Moscow, HSE University. (In Russ.)

Potapova E.G., Poteev P.M., Shklyaruk M.S. Digital transformation strategy: Write to execute (2021). Moscow, RANEPA. https://strategy.cdto.ranepa.ru/. (In Russ.)

Scenario modeling of the socio-economic effect of stimulating the acceleration of technological development of industry and increasing productivity of labor, including on the basis of digitalization: research report (2022). Moscow, Financial University. (In Russ.)

Exponential thinking, or The only path for business (2021). Moscow, Skolkovo School of Management. 9 July. https://www.skolkovo.ru/expert-opinions/eksponencialnoe-myshlenie-ili-edinstvennyj-put-dlya-biznesa/. (In Russ.)

Arica E., Oliveira M. (2019). Requirements for adopting digital B2B platforms for manufacturing capacity finding and sharing. In: *24th IEEE International Conference on Emerging Technologies and Factory Automation* (ETFA). IEEE: 703-709.

Barile S.S., Simone Ch., Iandolo F., Laudando A. (2022). Platform-based innovation ecosystems: Entering new markets through holographic strategies. *Industrial Marketing Management,* 105: 467-477.

Cozzolino A., Corbo L., Aversa P. (2021). Digital platform-based ecosystems: The evolution of collaboration and competition between incumbent producers and entrant platforms. *Journal of Business Research,* 126: 385-400.

García Á., Bregon A., Martínez-Prieto M.A. (2022). Towards a connected Digital Twin Learning Ecosystem in manufacturing: Enablers and challenges. *Computers & Industrial Engineering,* 171: 108463.

Greve H.R., Song S.Y. (2017). Amazon warrior: How a platform can restructure industry power and ecology. In: *Entrepreneurship, innovation, and platforms.* Bingley, Emerald Publishing Limited: 299-335.

Jose A., Tollenaere M. (2005). Modular and platform methods for product family design: Literature analysis. *Journal of Intelligent manufacturing,* 16(3): 371-390.

Hein A., Schreieck M., Riasanow T. (2020). Digital platform ecosystems. *Electronic Markets,* 30(1/13): 87-98.

Helfat C.E., Raubitschek R.S. (2018). Dynamic and integrative capabilities for profiting from innovation in digital platform-based ecosystems. *Research Policy,* 47(8): 1391-1399.

Jovanovic M., Sjödin D., Parida V. (2021). Co-evolution of platform architecture, platform services, and platform governance: Expanding the platform value of industrial digital platforms. *Technovation,* 102218.

Ko G., Amankwah-Amoah J. (2022). Non-market strategies and building digital trust in sharing economy platforms. *Journal of International Management,* 28(1): 100909.

Rho S., Lee M., Makkonen T. (2020). The role of open innovation platforms in facilitating user-driven innovation in innovation ecosystems. *International Journal of Knowledge-Based Development,* 11(3): 288-304.

Schreieck M., Wiesche M., Krcmar H. (2016). Design and governance of platform ecosystems – key concepts and issues for future research. In: *Proceddings of 24th European Conference on Information Systems* (ECIS). İstanbul, Turkey.

Silva H.D., Azevedo M., Soares A.L. (2021). A vision for a platform-based digital-twin ecosystem. *IFAC – PapersOnLine,* 54(1): 761-766.

Smart manufacturing ecosystems: A catalyst for digital transformation? (2020). https://www2.deloitte.com/us/en/pages/about-deloitte/articles/press-releases/2020-deloitte-and-mapi-smart-manufacturing-study-accelerating-smart-manufacturing.html?ysclid=l81ldgyvxa135376495.

Sun X., Zhang Q. (2021). Building digital incentives for digital customer orientation in platform ecosystems. *Journal of Business Research,* 137: 555-566.

Suuronen S., Ukko J., Eskola R., Semken R.S., Rantanen H. (2022). A systematic literature review for digital business ecosystems in the manufacturing industry: Prerequisites, challenges, and benefits. *CIRP Journal of Manufacturing Science and Technology,* 37: 414-426.

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Formation of a strategy and mechanism of interaction between participants of digital platforms

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Abstract

The article reviewed the literature in the framework of the study of digital platforms. The main types of digital platforms were considered: instrumental, infrastructural and applied. Within the framework of three types of digital platforms, the features of the of interaction mechanism between their participants are considered.

A study was also conducted in terms of determining the levels of interaction between participants of digital platforms within the framework of social, managerial, economic and technological activities. It was revealed that, in general, within the framework of digital platforms, their participants are characterized by a high level of relationships.

At the same time, the article conducted a study to determine the role of each participant in the development of their interaction within digital platforms of instrumental, infrastructural and applied types. It is revealed that the development of relationships between participants of digital platforms is influenced by the integration of all participants providing a synergistic effect.

Keywords: digital platforms, participants of digital platforms, the mechanism of interaction of participants, the relationship of participants of digital platforms, the roles of participants of digital platforms.

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Введение

In the modern world, there is an active change in the architecture of markets, a transition to platform technologies is underway, which is the main trend of the fourth industrial revolution. The main characteristic criteria of digital platforms are [Digital platforms.., 2018; Rohn et al., 2021]:

– algorithmisation of interaction between participants on digital platforms;
– mutually beneficial relations of all participants on digital platforms;
– a significant number of participants operating on digital platforms;
– ensuring a unified information environment for the effective functioning of digital platforms;
– reduction of transaction costs in the implementation of the interaction of various participants on digital platforms.

An important role in shaping the effective functioning of digital platforms is played by the participants, and the relationships built between them within a digital platform. This article discusses the mechanism of interaction between participants on digital platforms within three types of digital platforms.

Table 1
Supplier relationship management strategies

Strategy	Characteristic
Purchasing strategy development	This strategy assumes the centralisation of procurement, the development of procurement strategies for each product group, the formation of procurement quality strategies, the annual adjustment of the procurement strategy [Kushch, Smirnova, 2007; Shiralkar et al., 2022]
Supplier selection	Supplier selection and evaluation should include several steps [Urazova, 2009]: 1. Analysis of the range of purchased products 2. Determining the role of the supplier in the production processes 3. Determining the criteria for a good supplier in different categories 4. Supplier portfolio analysis and evaluation 5. Implementation of work with the supplier
Supplier development	The development of suppliers should be carried out primarily in two directions [Kushch, Smirnova, 2007]: • development aimed at strengthening the system of common values and goals with the supplier; • technological development
Communication process management	The formation of a strategy for communication processes with a supplier should be carried out at the level of the company's top management and take into account short-term and long-term relationships with the supplier. In modern conditions of high uncertainty and turbulence, it is preferable to build strategic (long-term) relationships with the supplier [Kushch, Smirnova, 2007]
Cost management	Cost management should include many aspects: supplier relationship management in terms of profitability, technology management, etc. [Kim, Choi, 2021]
Logistics management	Supply chain management can be carried out within various concepts - JIT, Kanban, etc. [Kim, Choi, 2021]
Monitoring	Supplier relationships should be continuously monitored [Kim, Choi, 2021]

Source: compiled by the author after [Kushch, Smirnova, 2007; Urazova, 2009; Kim, Choi, 2021; Shiralkar et al., 2022].

Table 2
Customer relationship management strategies

Strategy	Characteristic
Market segmentation	Formation of different groups (segments) to better meet the needs of business consumers [Sen, Sinha, 2011]
Choice of business consumers	Business consumers can choose within three strategies [Understanding business markets.., 1990]: • focusing on a particular market; • definition of benefits provided for each segment; • the ratio of values for the client and the level of costs
Building a portfolio of relationships	Preference is given to long-term strategic relationships with partners. In some cases, building short-term partnerships is possible [Hilton et al., 2020]

Source: compiled by the author according to [Understanding business markets.., 1990; Sen, Sinha, 2011; Hilton et al., 2020].

1. . Prerequisites for the formation of a mechanism for interaction between the company and partners

Let us consider the existing relationship management strategies in industrial companies.

There are several groups of strategies for managing a company's relationship with partners [Kushch, Smirnova, 2007]:

- supplier relationship management strategies;
- customer relationship management strategies;
- integrated models of relationship management between partner companies.

Groups of supplier relationship management strategies are presented in detail in Table 1.

At the same time, customer relationship management strategies also have their own classification (Table 2).

There are also integrated models for managing relationships between partner companies (Table 3).

Next, the main participants and their relationships within various types of digital platforms will be considered.

Table 3
Integrated models of relationship management between partner companies

Model	Characteristic
CPFR (Collaborative Planning, Forecasting and Replenishment)	Management of intercompany interactions through strict regulation and sequence of execution of all business processes. At the same time, forecasting and planning of business processes is carried out jointly between partners [Hill et al., 2018; Reusen, Stouthuysen, 2020]
JIT (Just in Time)	A logistics concept that allows just-in-time deliveries to be shared by all partners [Chen, Bidanda, 2019; Goyal et al., 2020]
TQM (Total Quality Management)	The concept of total quality management, which is aimed at improving the quality of all organisational processes of partners [Goyal et al., 2019; Wei et al., 2020]
LP (Lean Production)	The concept of lean production, which is aimed at eliminating waste of resources at all levels of production and involves production partners in this process [Rossini et al., 2019]

Source: compiled by the author after [Hill et al., 2018; Chen, Bidanda, 2019; Goyal et al., 2019; Rossini et al., 2019; Goyal et al., 2020; Reusen, Stouthuysen, 2020; Wei et al., 2020].

Table 4
Types of digital platforms

Type	Characteristics
Instrumental digital platform	It is based on a software or hardware-software complex (product) designed to create software or hardware-software solutions for applied purposes. Examples: Java, iOS, Microsoft Azure, Intel, SAP.HANA, etc.
Infrastructure digital platform	It is based on an ecosystem of participants in the informatisation market, the purpose of which is to accelerate the launch to the market and provide consumers in sectors of the economy with solutions to automate their activities (IT services) using end-to-end digital technologies for working with data and access to data sources implemented in the infrastructure of this ecosystems. Examples: PREDIX, ArcGIS, CoBrain, Era Glonass, Public Services, etc.
Applied digital platform	A business model for providing the possibility of an algorithmic exchange of certain values between a significant number of independent market participants by conducting transactions in a single information environment, leading to a reduction in transaction costs through the use of digital technologies and changes in the division of labor system. Examples: Yandex.Taxi, Avito, avasales, Plato, Booking.com, Uber, etc.
Industry digital platform	It includes participants in business processes of specific industries: manufacturing, trading and service companies, their customers, as well as government regulatory services. In technological terms, industry digital platforms are information systems for accumulating, exchanging and managing data in a structured form, as well as for calling business functions with information systems of platform participants connected to it through technological interfaces.

Source: compiled by the author based on [Digital Platforms.., 2018; Digital platforms, 2022].

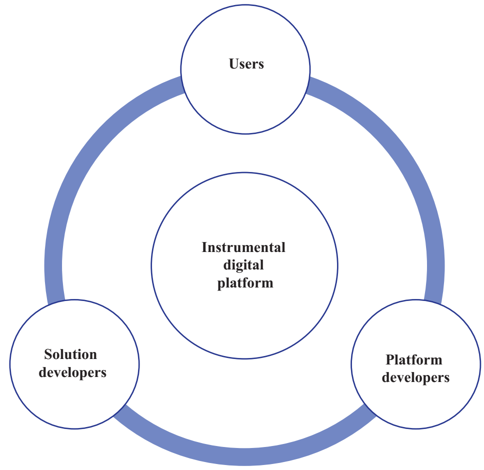
2. Main types of digital platforms

PJSC Rostelecom in the report gives the following definition of a digital platform: a digital platform is a system of algorithmic mutually beneficial relations between a significant number of independent participants in an industry (or field of activity) carried out in a single information environment, leading to a reduction in transaction costs through the use of digital technology package for working with data and changing the division of labor system [Digital Platforms.., 2018].

There are several types of digital platforms, which are presented in Table 4.

It should be noted that instrumental digital platforms make it possible to reduce the cost of developing software and hardware-software solutions. Infrastructural and applied digital platforms are aimed at reducing transaction costs [Digital platforms.., 2018].

Fig. 1. Coordination of the relationship management processes of the participants of the instrumental digital platform



Source: compiled by the author according to [Digital Platforms.., 2018; Galagan, 2019; Ratten, 2022; Xie et al., 2022].

Table 5
Mechanism of interaction of participants of the instrumental digital platform

Participants of instrumental digital platform	Mechanism of interaction / activities
Platform developers	• Ensuring the creation of a single technological platform: it is planned to create a single set of technologies, a single digital platform architecture, ensure the integration of the digital platform roadmap and the integration of digital platform components • Ensuring the creation of a single functional scope: the creation and formation of transactional components, analytical components, industry components • Formation of product history: it is planned to form a long-term strategy for the development of the company, the formation of detailed documentation, ensuring the functioning of the technical support service • High level of performance: providing support for horisontal and vertical clustering, generating metrics for internal testing of the digital platform • Ensuring the effectiveness of the digital platform functioning: effective implementation of the digital platform in the activities of an industrial company, attracting consumers and customers to the company, ensuring high rating positions of industrial companies
Solution developers	• Formation of solutions for instrumental digital platforms: development of business strategies, formation of the architecture of technical solutions, provision of technical support for business processes and digital products, implementation of end-to-end technologies, implementation of industry 4.0 technologies, ensuring IT infrastructure flexibility • Determining the needs of software product users, software and hardware solutions: conducting market research, market segmentation, building a portfolio of relationships, managing communication processes, training and developing users, ensuring continuous monitoring of relationships between participants in the instrumental digital platform • Forming a resource strategy: attracting resources for the smooth implementation of the company's business activities; ensuring sustainable competitive advantages through the formation and implementation of the resource strategy of an industrial company
Users	• Forming a large amount of data in an instrumental digital platform: this direction involves the formation of a large pool of information for subsequent storage, aggregation and use of data for making management decisions • Storage and processing of a large amount of data: software and hardware solutions of the instrumental digital platform are aimed at implementing the storage and processing of the entire pool of information contained in the digital platform • Making managerial decisions based on the processing of a large amount of data: within the framework of this direction, it is supposed to make managerial decisions and form strategies for an industrial company

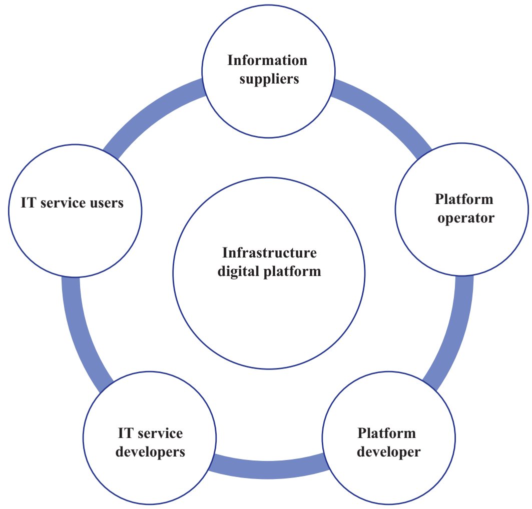
Source: compiled by the author after [Kushch, Smirnova, 2007; Galagan, 2019; Digital marketplace.., 2022; Ratten, 2022; Xie et al., 2022].

3. The mechanism of interaction between the participants of the instrumental digital platform

The work of instrumental digital platforms is based on the interaction of three groups of participants: platform developers, solution developers and users. Fig. 1 and Table 5 show the features of the mechanism of interaction between the participants of the instrumental digital platform.

It should be noted that all participants of the instrumental digital platform play significant roles in the formation of effective relationships and ensuring the functioning of the digital platform. The mechanism of the instrumental digital platform is built on the synergistic principle of interaction between participants to form software solutions for users of the instrumental digital platform [Kushch, Smirnova, 2007; Galagan, 2019; Digital marketplace.., 2022; Ratten, 2022; Xie et al., 2022].

Fig. 2. Coordination of the processes of managing the relationships of the participants of the infrastructure digital platform



Source: compiled by the author according to [Digital platforms.., 2018; Galagan, 2019; Wagner et al., 2021; Liu et al., 2022].

Table 6
Mechanism of interaction of participants of the infrastructure digital platform

Participants of the infrastructure digital platform	Mechanism of interaction / directions
Information supplier	Ensuring the provision of information services for individuals and legal entities Provision of services for individuals and legal entities
Platform operator	Management of communications with owners of information sources Data warehouse management of the digital platform Ensuring the functioning of business processes of a digital platform for developers of IT services Management of communications with the developer of infrastructure digital platform
Platform developer	Ensuring the creation of a single technology platform: it is planned to create a single set of technologies, a single digital platform architecture, ensure the integration of the digital platform roadmap and the integration of digital platform components Ensuring the creation of a single functional coverage: the creation and formation of transactional components, analytical components, industry components Formation of product history: it is planned to form a long-term strategy for the development of the company, the formation of detailed documentation, ensuring the functioning of the technical support service High level of performance: providing support for horisontal and vertical clustering, generating metrics for internal testing of the digital platform Ensuring the effectiveness of the functioning of the digital platform: effective implementation of the digital platform in the activities of an industrial company, attracting consumers and customers to the company, ensuring high rating positions for industrial companies
IT service developers	Development of IT services to ensure the effective functioning of digital platforms Ensuring integration and consistency
IT service users	Request for services provided within the applied digital platform Receiving services provided within the infrastructure digital platform Use of related IT services and digital platforms

Source: compiled by the author according to [Digital Platforms.., 2018; Galagan, 2019; Wagner et al., 2021; Choosing a Transformational Solution, 2022; Liu et al., 2022; Approaches to the definition.., no date].

4. Mechanism of interaction between participants of the infrastructure digital platform

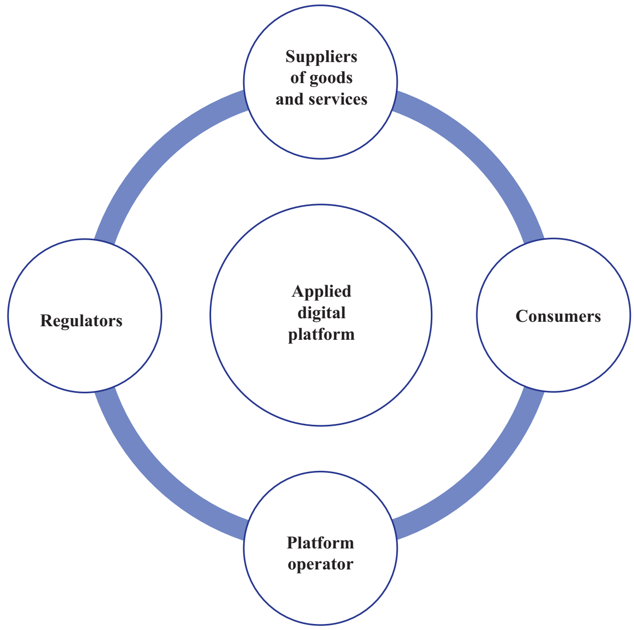
The functioning of infrastructure digital platforms is based on the interaction of five groups of participants: platform developers, platform operators, information providers, users of IT services, developers of IT services. Fig. 2 and Table 6 show the features of the interaction mechanism for participants in the infrastructure digital platform.

It should be noted that in the infrastructure digital platform, the functions and roles of participants are similar to the functions and roles of participants in the instrumental type of digital platforms: for example, developers of a digital platform must ensure a unified technological system of the digital platform and the effective functioning of the platform. However, the infrastructure digital platform, unlike the instrumental platform, provides consumers in various sectors of the economy with solutions to automate their activities based on end-to-end digital technologies for working with data and access to data sources that are implemented in the ecosystem infrastructure. At the same time, infrastructural digital platforms make it possible to provide services for legal entities in various sectors of the economy [Digital platforms.., 2018; Galagan, 2019; Wagner et al., 2021; Choosing a Transformational Solution, 2022; Liu et al., 2022; Approaches to the definition.., b.g.].

5. Mechanism of interaction between participants of the applied digital platform

The work of applied digital platforms is based on the interaction of four groups of participants: suppliers of goods and services, platform operator, consumers, regulators.

Fig. 3. Coordination of the relationship management processes of the participants of the applied digital platform



Source: compiled by the author according to [Digital Platforms.., 2018; Stecken et al., 2019; Cozzolino et al., 2021].

Features of the interaction mechanism of applied digital platforms are shown in Fig. 3 and in Table 7.

The mechanism of applied digital platforms allows for the exchange of values between a significant number of sellers and buyers. The ability to exchange value is the main distinguishing feature of applied digital platforms from others [Stecken et al., 2019; Cozzolino et al., 2021; Approaches to the definition.., no date.].

Thus, the proposed mechanisms for building digital platforms will allow to:

Table 7
Mechanism of interaction of participants of the applied digital platform

Participants of the applied digital platform	Mechanism of interaction/directions
Suppliers of goods and services	Providing all necessary information about goods and services Sale of goods and services
Platform operator	Management of communications with owners of information sources Data warehouse management of the digital platform Ensuring the functioning of business processes of a digital platform for developers of IT services Managing communications with the developer of the applied digital platform
Consumers	Request for goods and services provided within the applied digital platform Purchase of goods and services provided within the application platform Use of related IT services and digital platforms
Regulators	Ensuring legal requirements Implementation of monitoring and regulation of economic activity

Source: compiled by the author according to [Stecken et al., 2019; Cozzolino et al., 2021; Approaches to the definition.., no date.].

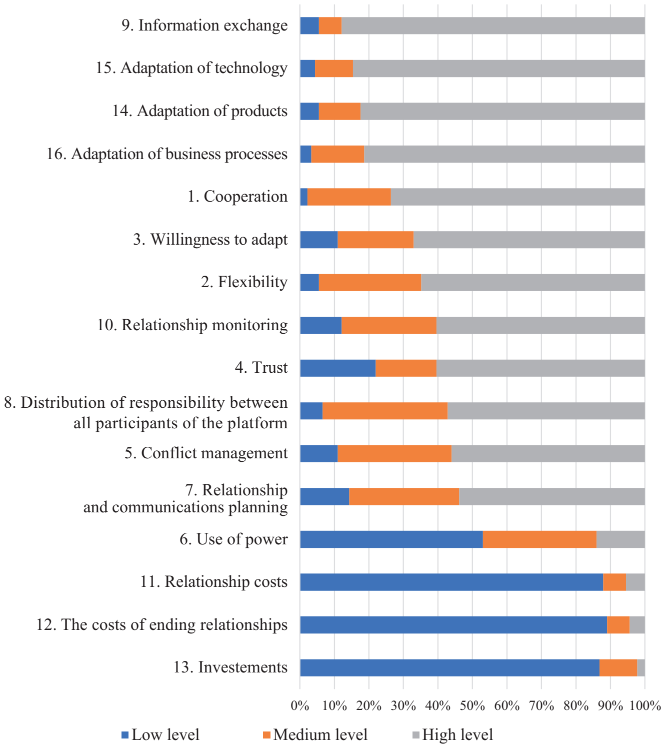
- ensure integration of services, technologies and participants of digital platforms;
- reduce transaction costs and increase competitiveness;
- ensure the efficiency of the digital platform.

6. The main characteristics of the interaction mechanism between participants on digital platforms

As part of this work, a study was conducted to identify various aspects in the relationship between participants on digital platforms. The study was conducted on the basis of the methodology presented in the scientific report by S. Kushch and M. Smirnova "The mechanism for coordinating the processes of managing the company's relationship with partners" [Kushch, Smirnova, 2007]. In their study, they considered the most important characteristics of the mechanism of dual relationships "consumer - key supplier" in the following areas of relationship analysis: social, economic, managerial and technological. The author of this work considered the same aspects but within the framework of the interaction mechanism between participants on digital platforms.

The study was conducted in two stages: conducting a survey of experts to determine the level of relationship between participants on digital platforms; processing of

Fig. 4. Levels of relationships between participants of digital platforms



Source: compiled by the author.

Table 8
Description of the sample of industrial companies participating in the study

Industry	Number of companies in the sample	Share of companies in the sample (%)
Mining	10	11
Production of consumer goods	18	20
Chemical production	14	15
Manufacture of machinery and equipment, including electrical equipment	9	10
Cosmetic and pharmaceutical industry	19	21
Other	21	23

Source: compiled by the author.

Table 9
The main directions of the mechanism of interaction of participants of digital platforms

Mechanism line	Line aspects
Social	1. Cooperation 2. Flexibility 3. Willingness to adapt 4. Trust 5. Conflict management 6. Use of power
Managerial	7. Relationship and communication planning 8. Distribution of responsibility between all participants of the digital platform 9. Information exchange 10. Relationship monitoring
Economic	11. Relationship Costs 12. Costs of termination of relationship 13. Investments
Technological	14. Product customisation 15. Technology adaptation 16. Adaptation of business processes

Source: compiled by the author according to [Kushch, Smirnova, 2007; Silva et al., 2021].

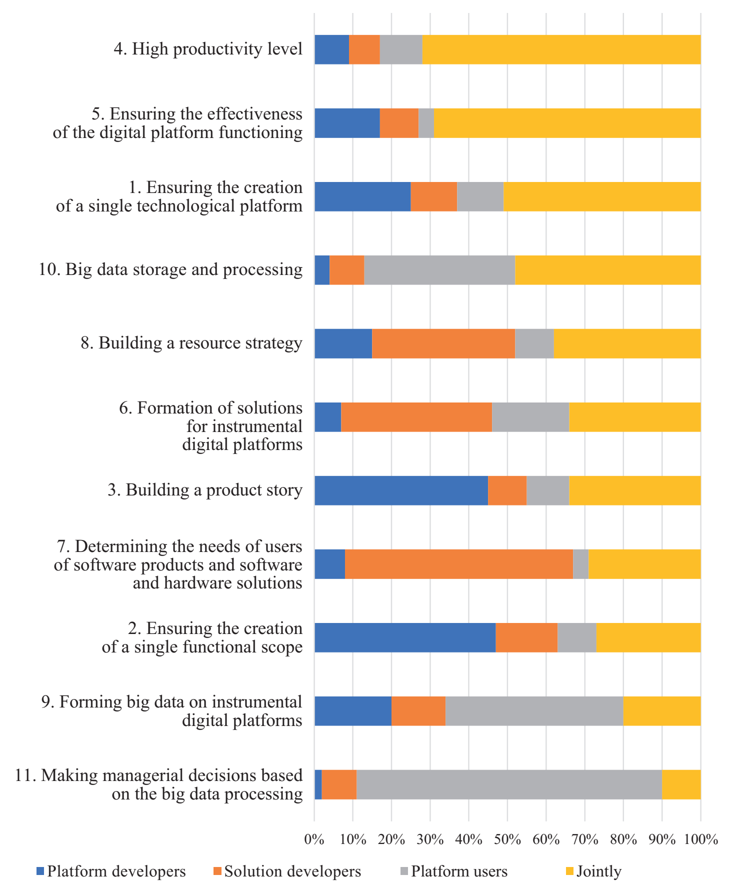
received information. Let us consider each stage of the study in more detail.

At the first stage of the study, a survey of 91 industrial companies was conducted. The main criterion for selecting companies was their consent to participate in a study to determine the level of relationships between participants in digital platforms. Table 8 provides a description of a sample of industrial companies.

The experts were asked to assess the level of the relationship between the participants of digital platforms by determining the level of each of the four areas (Table 9). It is important to note that if the aspects of the line are low, this does not mean that the level of relationships between participants in digital platforms is low. For example, in order to state that the level of relations between participants on digital platforms within the framework of an economic line is high, it is necessary to have a low level of aspects of this line (that is, a low level of costs and investments).

At the second stage of the study, the information obtained during the survey of experts was processed; the results of the study are presented in Fig. 4.

Fig. 5. The role of the participants of the instrumental digital platform in the development of their relationships



Source: compiled by the author.

Social direction. As part of the functioning of digital platforms, most experts note a fairly high level of relationships according to the social direction. According to experts, such social aspects as cooperation, flexibility, willingness to adapt, trust, conflict management are at a high level. The use of power is noted as a low-level social aspect, since the functioning of digital platforms makes it possible to increase the transparency of work and improve monitoring of relationships and communications between participants on a digital platform, which makes it possible to ensure work according to uniform rules and standards for all participants [Kushch, Smirnova, 2007; Silva et al., 2021].

Management direction. According to the interviewed experts, digital platforms allow to build a high level of relationships in the management area. This is confirmed by the fact that the planning of relationships and communications, the distribution of responsibility between all participants on the digital platform, the exchange of information, and the monitoring of relationships are built at a high level due to the introduction of a digital platform at an industrial enterprise [Kushch, Smirnova, 2007; Silva et al., 2021].

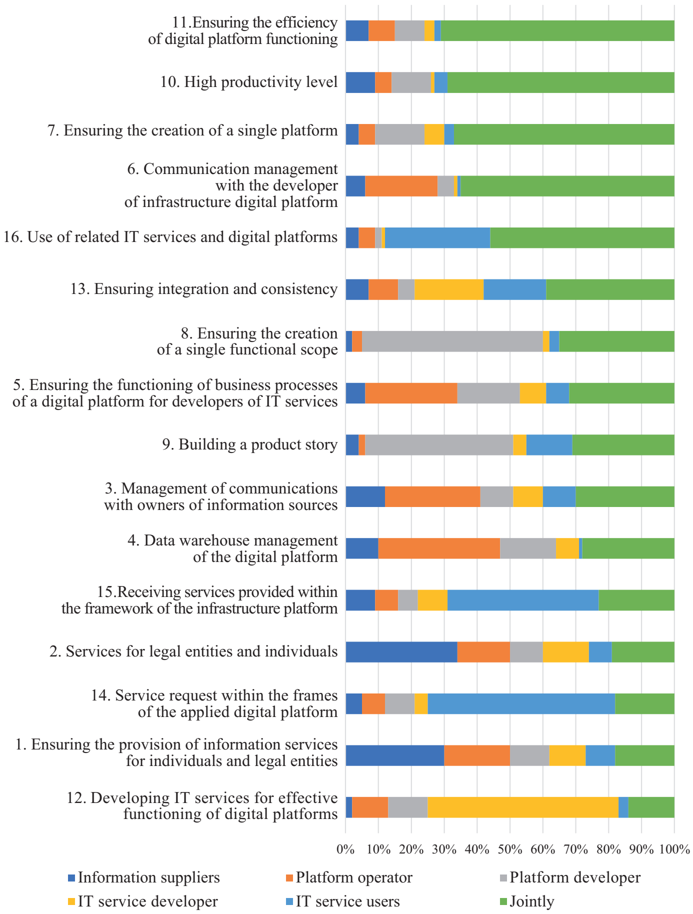
Economic direction. The introduction of digital platforms in industrial enterprises can significantly reduce costs, which is confirmed by the results of the survey. The costs of maintaining relationships, the costs of terminating relationships and investments are reduced due to the operation of the digital platform, which confirms the high level of relationships in the field of economic direction [Kushch, Smirnova, 2007; Silva et al., 2021].

Technological direction. The relationship of participants within the technological aspect is also at a high level due to the introduction of digital platforms; it is confirmed by experts. Adaptation of products, technologies and business processes is recognised as being at a high level [Kushch, Smirnova, 2007; Silva et al., 2021].

The article also conducted a study to determine the role of each participant in the development of their interaction within three types of digital platforms. The study was based on the methodology presented in the already mentioned report [Kushch, Smirnova, 2007]. This study was conducted in two stages: conducting a survey of experts to identify the preferences of industrial companies in terms of the roles of participants in digital platforms in the development of their interaction; processing the information received from the results of the survey. Let's consider each stage of the study in more detail.

At the first stage, a survey of 91 industrial companies was conducted (Table 8). In the questionnaires, it was proposed to determine the

Fig. 6. The role of the participants of the infrastructure digital platform in the development of their relationships (% of respondents)



Source: compiled by the author.

role of each participant in the development of interaction between instrumental, infrastructure and applied digital platforms. As the roles of participants in digital platforms, the areas of activity of each participant were indicated, described in Tables 5-7.

At the second stage of the study, the information obtained during the survey of experts was processed. The results of the study are presented in Fig. 5-7.

Thus, the development of relationships between the participants of the instrumental digital platform is influenced by the integration of all participants in the implementation of the following roles:

- high level of productivity;
- ensuring the efficiency of the digital platform;
- ensuring the creation of a single technological platform;
- bid data storage and processing;
- forming a resource strategy.

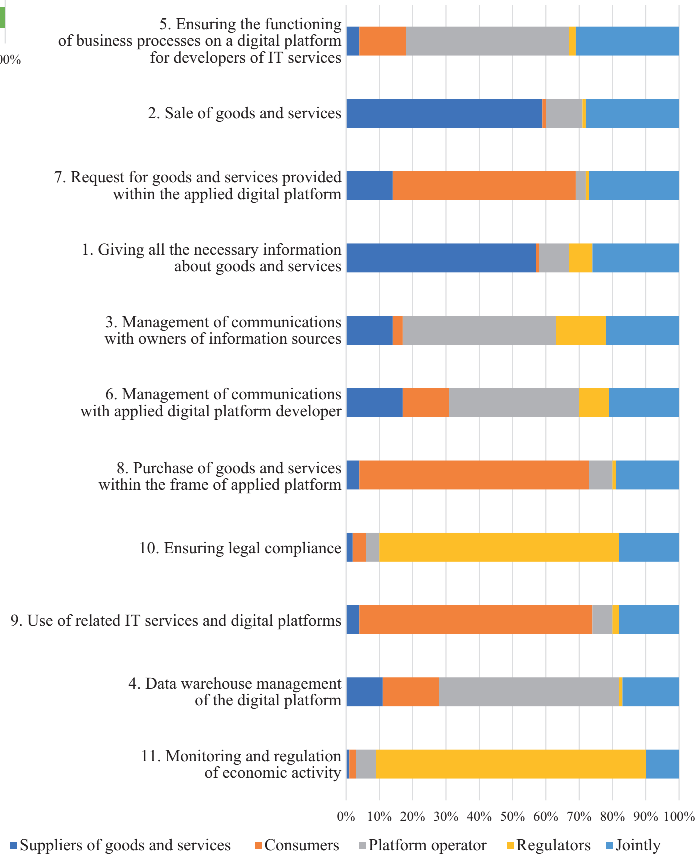
Thus, the development of relationships between participants on the infrastructure digital platform is influenced by the integration of all participants in the implementation of the following roles:

- ensuring the efficiency of the digital platform;
- high level of productivity;
- ensuring the creation of a single technological platform;
- communication management with the developer of the infrastructural digital platform;
- use of related IT services and digital platforms.

Thus, the development of relationships between participants on the applied digital platform is influenced by the integration of all participants in the implementation of the following roles:

- ensuring the functioning of business processes of the digital platform for developers of IT services;
- sale of goods and services;
- request for goods and services provided within the applied digital platform;
- provision of all necessary information about goods and services;
- management of communications with owners of information sources.

Fig. 7. The role of the participants of the applied digital platform in the development of their relationships



Source: compiled by the author.

7. Conclusions and results

The article considers the features of the mechanisms on digital platforms of instrumental, infrastructure and applied types. Instrumental digital platforms allow to reduce the cost of developing software and hardware-software solutions. Infrastructural and applied digital platforms are aimed at reducing transaction costs. The work of instrumental digital platforms is based on the interaction of three groups of participants: platform developers, solution developers and users. The functioning of infrastructure digital platforms is based on the interaction of five groups of participants: platform developers, platform operator, information providers, users of IT services, developers of IT services. The work of applied digital platforms is based on the interaction of four groups of participants: suppliers of goods and services, the platform operator, consumers, and regulators. The proposed mechanisms for building digital platforms are aimed at:

- ensuring the integration of services, technologies and participants of digital platforms;
- reduction of transaction costs and increase of competitiveness;
- ensuring the efficiency of the digital platform.

In this work, a study was conducted to identify various aspects in the relationship between participants in digital platforms, which showed that the relationship between participants in digital platforms is at a high level in four areas: social, managerial, economic and technological. This was confirmed based on a survey of experts.

The author also conducted a study to determine the role of each participant in the development of their relationships within digital platforms of instrumental, infrastructure and applied types. Based on the results of participants' roles study on the instrumental digital platform, it was revealed that for the development of their relationship it is important to ensure the integration of participants in the following areas: high level of productivity, ensuring the effectiveness of the functioning of the digital platform, ensuring the creation of a single technological platform, storage and processing of large amounts of data, formation of a resource strategy. According to the results of participants' roles study on the infrastructure digital platform, for the development of their relationship, it is important to ensure the integration of participants in the following areas: ensuring the effectiveness of the digital platform functioning, high level of performance, ensuring the creation of a single technological platform; managing communications with the developer of the infrastructure digital platform, use of related IT services and digital platforms. The results of participants' roles study on the applied digital platform showed that in order to develop their relationship, it is important to ensure the integration of participants in the following areas: ensuring the functioning of business processes of the digital platform for developers of IT services, sale of goods and services, request for goods and services provided within the applied digital platform, providing all the necessary information about goods and services, management of communications with the owners of information sources. Thus, the development of relationships between participants on digital platforms is influenced by the integration of all participants, which provides a synergetic effect.

References

Choosing a transformational solution (2022). Training Center for Leaders and Digital Transformation Teams. https://strategy.cdto.ranepa.ru/6-2-cifrovye-proekty-i-platformy. (In Russ.)

Galagan D. (2019). *Tool platforms. The core of digital transformation of authorities*. IBS. https://www.tadviser.ru/images/8/83/5.%D0%93%D0%B0%D0%BB%D0%B0%D0%B3%D0%B0%D0%BD_28.05.19_19.pdf. (In Russ.)

Kushh S.P., Smirnova M.M. (2007). *The mechanism for coordinating the processes of managing the company's relationship with partners.* Scientific reports 6(R). Saint Petersburg, SPbGU. https://dspace.spbu.ru/bitstream/11701/820/1/6%28R%29_2007.pdf. (In Russ.)

Approaches to the definition and typification of digital platforms (w.y.). https://files.data-economy.ru/digital_platforms_project.pdf. (In Russ.)

Urazova N. (2009). Supplier selection and evaluation. *ElektroInfo journal,* 1. https://www.cfin.ru/management/manufact/supplier_choice_and_evaluation.shtml. (In Russ.)

Digital marketplace: Catalog of the Russian software (2022). Digital platforms. https://diplatforms.ru/project/digitalmarketplace. (In Russ.)

Digital platforms. Approaches to definition and typification (2018). Rostelecom. https://d-russia.ru/wp-content/uploads/2018/04/digital_platforms.pdf. (In Russ.)

Digital platforms (2022). Competence Development Center in Business Informatics, Logistics and Project Management of the Higher School of Business. https://hsbi.hse.ru/articles/tsifrovye-platformy/. (In Russ.)

Chen Zh., Bidanda B. (2019). Sustainable manufacturing production-inventory decision of multiple factories with JIT logistics, component recovery and emission control. *Transportation Research Part E: Logistics and Transportation Review,* 128: 356-383. https://doi.org/10.1016/j.tre.2019.06.013.

Cozzolino A., Corbo L., Aversa P. (2021). Digital platform-based ecosystems: The evolution of collaboration and competition between incumbent producers and entrant platforms. *Journal of Business Research,* 126: 385-400. https://doi.org/10.1016/j.jbusres.2020.12.058.

Goyal A., Agrawal R., Saha C.R. (2019). Quality management for sustainable manufacturing: Moving from number to impact of defects. *Journal of Cleaner Production,* 241. https://doi.org/10.1016/j.jclepro.2019.118348.

Goyal S., Ahuja M., Kankanhalli A. (2020). Does the source of external knowledge matter? Examining the role of customer co-creation and partner sourcing in knowledge creation and innovation. *Information & Management,* 57(6). https://doi.org/10.1016/j.im.2020.103325.

Hill C.A., Zhang G.P., Miller K.E. (2018). Collaborative planning, forecasting, and replenishment & firm performance: An empirical evaluation. *International Journal of Production Economics,* 196: 12-23. https://doi.org/10.1016/j.ijpe.2017.11.012.

Hilton B., Hajihashemi B., Henderson C.M., Palmatier R.W. (2020). Customer success management: The next evolution in customer management practice? *Industrial Marketing Management,* 90: 360-369. https://doi.org/10.1016/j.indmarman.2020.08.001.

Kim Y., Choi T.Y. (2021). Supplier relationship strategies and outcome dualities: An empirical study of embeddedness perspective. *International Journal of Production Economics,* 232. https://doi.org/10.1016/j.ijpe.2020.107930.

Liu Y., Wu A., Song D. (2022). Exploring the impact of cross-side network interaction on digital platforms on internationalization of manufacturing firms. *Journal of International Management.* https://doi.org/10.1016/j.intman.2022.100954.

Ratten V. (2022). Digital platforms and transformational entrepreneurship during the COVID-19 crisis. *International Journal of Information Management.* https://doi.org/10.1016/j.ijinfomgt.2022.102534

Reusen E., Stouthuysen K. (2020). Trust transfer and partner selection in interfirm relationships. *Accounting, Organizations and Society,* 81. https://doi.org/10.1016/j.aos.2019.101081.

Rohn D., Bican P.M., Brem A., Kraus S., Clauss Th. (2021). Digital platform-based business models – An exploration of critical success factors. *Journal of Engineering and Technology Management,* 60. https://doi.org/10.1016/j.jengtecman.2021.101625.

Rossini M., Costa F., Staudacher A.P., Tortorella G. (2019). Industry 4.0 and lean production: An empirical study. *IFAC-PapersOnLine,* 52(13): 42-47. https://doi.org/10.1016/j.ifacol.2019.11.122.

Sen A., Sinha A.P. (2011). IT alignment strategies for customer. *Decision Support Systems,* 51(3): 609-619. https://doi.org/10.1016/j.dss.2010.12.014.

Shiralkar K., Bongale A., Kumar S. (2022). Issues with decision making methods for supplier segmentation in supplier relationship management: A literature review. *Materials Today: Proceedings,* 50(5): 1786-1792. https://doi.org/10.1016/j.matpr.2021.09.197.

Silva H.D., Azevedo M., Soares A.L. (2021). A vision for a platform-based Digital-Twin ecosystem. *IFAC-PapersOnLine,* 54(1): 761-766. https://doi.org/10.1016/j.ifacol.2021.08.088.

Stecken J., Ebel M., Bartelt M., Poeppelbuss J., Kuhlenkötter B. (2019). Digital shadow platform as an innovative business model. *Procedia CIRP,* 83: 204-209. https://doi.org/10.1016/j.procir.2019.02.130.

Ford D. (ed.). *Understanding business markets. Interaction, relationships and networks* (1990). London, Academic Press.

Wagner G., Prester J., Pare G. (2021). Exploring the boundaries and processes of digital platforms for knowledge work: A review of information systems research. *The Journal of Strategic Information Systems,* 30(4). https://doi.org/10.1016/j.jsis.2021.101694.

Wei F., Feng N., Yang Sh., Zhao Q. (2020). A conceptual framework of two-stage partner selection in platform-based innovation ecosystems for servitization. *Journal of Cleaner Productio,* 262. https://doi.org/10.1016/j.jclepro.2020.121431.

Xie X., Han Y., Anderson A., Ribeiro-Navarrete S. (2022). Digital platforms and SMEs' business model innovation: Exploring the mediating mechanisms of capability reconfiguration. *International Journal of Information Management,* 65. https://doi.org/10.1016/j.ijinfomgt.2022.102513.

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Strategy for building digital platforms for industrial waste management

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Abstract

In modern conditions, to increase the efficiency of industrial waste management, a radical transformation of the business processes within industry enterprises, the introduction of modern digital technologies, the use of platform business models are required. The purpose of the article is to study the role of digital platforms to improve the efficiency of interaction between companies working in the field of waste disposal and recycling. The study analyses the participation of internal and external company stakeholders in the industrial waste processing industry. Empirical analysis is carried out on the basis of qualitative and quantitative analysis based on in-depth expert interviews. The sample includes interviews with the heads of 150 Russian industrial waste processing enterprises. All the companies considered have practical experience on digital platforms.

Keywords: digital platforms, stakeholders, recycling, industrial waste.

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Introduction

Waste management has traditionally been a physical and mechanical sector specialised in the collection, sorting, recycling, or incineration of waste. It is expected that digital platforms will have the potential to serve multiple purposes for industrial waste processing enterprises, for example, when integrated into the concept of "Industry 4.0". The problem of industrial waste in the world can be solved through cooperation with all stakeholders involved in the waste value chain, from upstream to downstream. However, it is increasingly being targeted by solution providers who promise more efficient and effective operations through digital technologies such as smart containers, on-demand semi-autonomous trucks, or artificial intelligence for material recognition and robotic automation. The introduction of digital platforms in the waste sector has also led to a transformation in the cost structure, which affects both technological and financial choices.

The main problem of this study is to find out the relationship between the stakeholders of waste management enterprises and digitalisation.

1. Literature review

1.1. Role of digital platforms

Platform business has become one of the latest research topics in a number of management disciplines. The platform serves as an interface that facilitates interaction between different parties, usually complementaries and clients. For example, Amazon, the Tambouris world's largest e-commerce retailer, has over 2.5 million merchants offering customers over 12 million items [Tiwana, Ramesh, 2001; Knoeri et al., 2011; Bonina et al., 2021]. A recent article in the *Journal of Management* reports that the literature on platforms is largely shaped from the perspective of an industrial organisation that sees platforms as two-sided or multi-sided markets in which transactions and interactions between complementary parties and customers take place. The theoretical constructs in such studies are mainly focused on the interdependence between different parties in the market, network effects and platform competition. At the same time, a new perspective is rapidly developing that moves away from the prevailing concept as it more clearly conceptualises the platform and its associated complementary elements as the creation of a unique organisational form or "meta-organisation" [Asadullah, Kankanhalli, 2018].

This organisation-centric perspective emphasises the interdependence between platforms and complementaries, that is, how platform owners manage relationships with complementaries and how the collective actions of complementers and partner firms determine the success of a platform. Notably, [Heidrich, Harvey, 2008] gives a compelling account of how platforms resemble the hybrid organisations familiar to strategists and management professionals. They argue that platforms "can be seen as hybrid structures between organisations and markets, providing a mix of market and hierarchical power, and a mix of market and hierarchical incentives." The implicit assumption underlying this literature is that studying the strategy of platform owners is the key to understanding platforms as meta-organisations, since by providing and controlling the use of critical production assets, platform owners are the link in multilateral relationships [Neves da Rocha, Pollock, 2019].

Developing this point of view, we see the platform as an alternative to the "firm against the market" to solve the managerial problem of coordinating the diverse activities and interests of partner firms [Rochet, Tirole, 2003; Jingyi Wang, Tao Bai, 2021]. More strikingly, we notice that an important characteristic of a platform in today's world is its use of digital technology to create and capture value. Embracing digital transformation not only facilitates the incubation of new products and services for customers, but also significantly changes the way platform owners develop certain tools to achieve the desired platform management outcomes. E-commerce platforms such as Alibaba and JD.com [Cremona, Lin, 2014; Cane, Parra, 2020] use instant messaging capabilities to enable complementary businesses to obtain customer information and respond quickly to customer requests and needs, while taxi booking platforms, such as Didi and Lyft [Berg, Wilts, 2019; Neves da Rocha, Pollock, 2019] use digitization technology that keeps complementers from misbehaving offline. Mobile operating systems such as Android use a modular architecture that provides complementaries with autonomy to carry out value-creating activities, while online feedback systems are mainly used on e-commerce platforms to evaluate seller performance and drive corrective action. It is with the help of these digital technologies that platforms can better coordinate activities within an organisation and become modern hybrids that combine elements of markets with hierarchies. Therefore, in order to deepen our knowledge about the impact of digital technologies on platform management, we pay special attention to digital platforms, which are a type of platform that serves as a standardised digital interface and uses digital technologies to facilitate interaction between different parties. We believe that, in addition to looking at traditional management mechanisms such as pricing, direct integration, or contracting, understanding how organsational relationships resort to digital means of coordination will offer a much-needed technological lens to push the boundaries of organisational management research [Rochet, Tirole, 2003; Kovacic et al., 2020].

Definition of digital platforms

Researchers in industrial organisations usually interpret a platform as a specific type of market that facilitates interaction between different groups of participants, such as complementaries and consumers, and interdependence within or between these groups gives rise to "network externalities," which describe how the utility of a user increases with the number of other users on the same side (i.e., direct network effects) or the other side (i.e., indirect network effects) of the platform market. Following this perspective, earlier work on platforms has explored in detail how various market mechanisms (e.g., pricing structures) are used by traditional marketplaces (as diverse as malls, bazaars, and newspapers) or network industries to create network effects and shape market dynamics. In contrast, little attention has been paid to the various interactions between platform owners and platform complementaries, or the impact of platform architecture on the participation of platform complementaries [Asadullah, Kankanhalli, 2018].

However, inspired by the emergence of new platform business models, a growing number of scholars are looking at how digital technology has enabled platform owners to coordinate the activities of various parties on the platform. Digital platforms refer to a type of platform that serves as a standardised digital interface and use digital technologies to facilitate interaction between different parties. For example, Uber is a digital platform that uses its big data analytics and matching algorithms to provide a passenger with the most suitable driver. Thanks to the principles of modular design, the functionality of digital platforms can be extended by independent heterogeneous agents that use standardised interfaces and platform components, on the basis of which these agents can create their own additional products. In addition, digital platforms go beyond conventional market mechanisms by using digital tools to coordinate activities within an organisation. For example, when coordinating who can use which resources on a platform, in addition to setting go-to-market criteria to weed out low-quality complements, digital platforms (e.g., Github, iOS, Android) can selectively expose their interface by setting limits about the use of software tools by complementaries, such as APIs and SDKs. Such design features reflect the unique ability of digital platforms to orchestrate the value-creating activities of complementers without explicitly calling out contracts or hierarchies. However, this ability has not been systematically explored in the platform literature [Kintscher et al., 2020].

Organisational perspective of digital platforms

Recent research has begun to examine platforms as an organisational form [Cremona, Lin, 2014] from an organisational standpoint [Berg, Wilts, 2019]. Organisations are characterised by "the conscious and deliberate coordination of activities within identifiable boundaries, in which members come together on a regular basis through a series of implicit and explicit agreements, committing to act collectively to create and allocate resources and capabilities through a combination of command and cooperation." In understanding the various forms of non-contractual inter-organisational collaboration, [Tiwana, Ramesh, 2001] offer one of the pioneering attempts to conceptualise platforms as a type of meta-organisation in which legally autonomous entities (firms and individuals) are subject to the informal authority of the platform firm. Holger and others [Asadullah, Kankanhalli, 2018] represent the latest recognition of this important shift in the conceptualisation of platforms by academic managers, i.e., from pricing to management, as they seek to make the connection between platforms and hybrids. Thus, hybrids will be characterised by a specific combination of market incentives and modalities of coordination involving some form of hierarchical relationship.

There are two notable similarities between digital platforms and our established understanding of hybrids. In hybrid organisations, interfirm relationships are only loosely contractualised, and relationships are rooted in technological complementarity or organisational synergy.

On digital platforms, complementarity between co-specialising producers (e.g., platform owners and complementaries) similarly underlies the emergence of a cooperative organisation. Indeed, the very logic of the organisation as a platform is to use the generative potential of the distributed innovation agency and the specialisation economy. Second, hybrids rely on partners to pool strategic resources and share decision-making rights while maintaining separate ownership of key assets, so special devices are required to coordinate partner collaboration and arbitrate rewards. Similarly, digital platforms are organised according to a set of relational contracts whereby platform owners transfer decision-making rights across borders, and complements in turn waive some remuneration rights to platform owners [Schmalensee, 2014].

Digital transformation for social innovation business models

Digital platforms rely on Internet technologies to bring together multiple stakeholders. Social entrepreneurs who strive for continuous improvement and innovation in business models should invest in digital transformation. It is important to use an approach that understands the dynamic impact of technology on business [Schmalensee, 2014].

The platform may rely on algorithms to improve the quality of matching, increase participation and engagement. This can automate more tasks, collect data for analytics, and provide a superior experience for stakeholders and platform employees. The platform can use digital technologies to segment stakeholders. It can create premium profiles for non-profit organisations and other stakeholders who want to use the platform more intensively and need additional support. Another opportunity is to use digital technologies to expand the range of stakeholders.

Finally, the digital and non-digital elements of the platform must be well designed and coordinated. Humans must meticulously perform any task that is not easy to automate. This ensures that all stakeholders of the platform will have a consistent experience. Platform developers should also be aware of cost-based design approaches and issues.

1.2. Digital platform in recycling

Although intensive industrialisation has boosted global GDP, waste production is still recognised as a blind spot in manufacturing. With a growing shortage of critical raw materials, the second life of products and used materials is becoming an inevitable option to advance the circular economy. Consequently, industrial users are gradually moving from a linear economy to a circular economy in waste management. This contributes to the recovery of resources through recycling and reduces the negative impact of the linear economy. For this reason, identifying new opportunities and challenges associated with the recycling, reuse, and recovery (3R) scheme is important to develop and deploy suitable technologies that drive innovative digitalisation [Tambouris, Migotzidou, 2015].

In an increasingly complex, interdependent, and interconnected era, digitalisation is playing a critical role in the waste sector in building a global sustainable economy, changing the way companies do business, how they organise business, and how they create and use value.

Technological progress allows digitalisation to offer practical solutions for the waste sector with long-term benefits for society. Digitalisation, which embraces the circular economy of waste recycling, has become a driving force behind the growth in value creation by improving the efficiency of resource recovery operations and reducing operating costs with traceability of waste streams. Fig. 1 shows the digital platform for industrial waste management.

The recycling sector has the potential to seize the opportunities of a circular economy through digitalisation. Although landfill is a main tool for waste disposal, the future lies in digitalising waste recycling in the market.

Embracing digitisation in the waste industry will keep the recycling system running and businesses alive. This helps the waste industry to move towards sustainable solutions with the ability to trace waste streams.

Internet + digital platform processing, based on enterprise industry characteristics. There are three main actors involved in the maintenance of the digital recycling platform: producers, consumers, and platforms. The recycling platform brings together consumers and producers from both sides, which together constitute a two-sided market for the operation of the recycling platform. When consumers need to recycle waste, they submit the relevant information to the digital platform through online recycling websites or offline recycling stores, and the platform will match the relevant manufacturers based on the type of waste, recyclability, and details, as well as other information provided by consumers.

As more consumers choose a recycling platform, the remanufacturing opportunities that manufacturers get through the platform will increase, and as more and more manufacturers join the digital platform, competitive pressure will increase and service quality will improve.

Policymakers, practitioners, and scientists have long touted digital technologies such as smart waste containers or artificial intelligence for material recognition and robotic automation as key tools for more efficient and effective waste management. While these advances promise an increasingly digital future for waste collection, sorting, and recycling, little is known about the current level of digitalisation of waste management companies.

Digital recycling platforms are managed by a recycling management system that is limited to policy oversight. In addition, the recycling management system is governed by policies, and relevant policy rules are put forward for the digital recycling platforms it manages. In turn, the achievements of digital recycling platforms also receive feedback from the entire recycling management system, which can be both positive and negative [Xiaodong Zhu, Wei Li, 2021].

1.3 Recycling stakeholders

The term "recycler" generally refers to different types of stakeholders in the recycling system, although in a restrictive sense, it refers to a recycler who performs the necessary processes with recyclable materials that result in usable materials. The recycling system includes the trading (buying and selling) of waste that is considered waste. Stakeholders are those who participate in the recycling system [Kojima, 2008].

The simplified approach made it possible to shape a criterion based on the significance of the stakeholders for the processing enterprise, dividing them into two groups:

- key stakeholders – they have a direct impact on the organisation's activities;
- secondary stakeholders are – non-governmental organisations and the media that influence the actions of the main stakeholders through the formation of public opinion.

Trade relations between types of recyclers affect the level of trade as well as the flow of recyclables within the country and to foreign countries.

Stakeholders of processing companies are proposed to be classified into internal and external. Key stakeholders include: shareholders and investors; employees; customers; suppliers; governments and communities. However, the division of stakeholders into internal and external is quite obvious. The trading system and specific types of stakeholders are described in table 1.

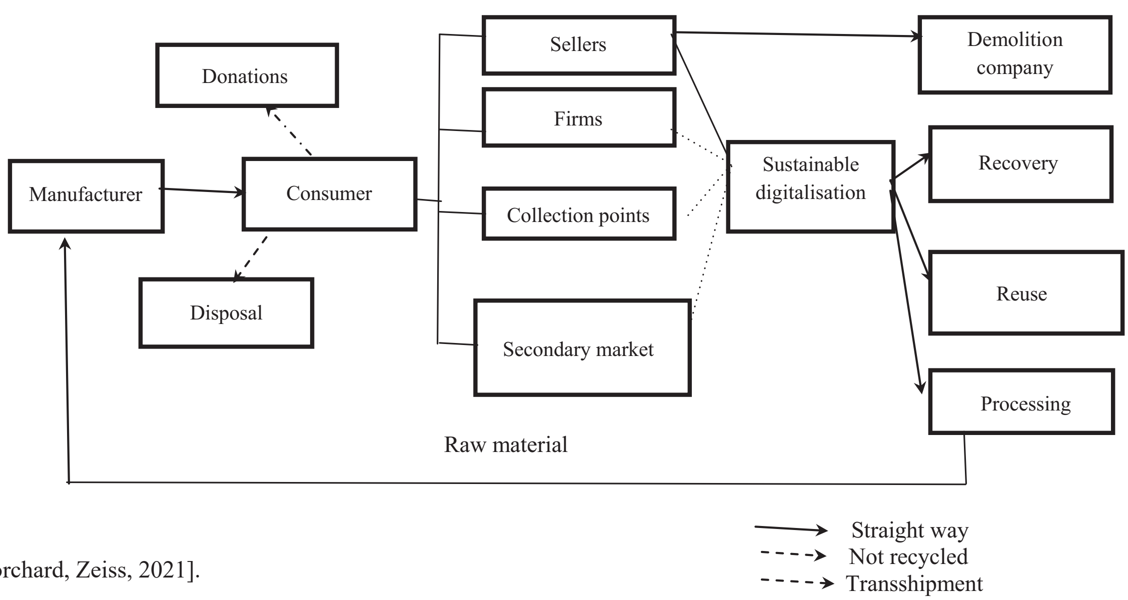
Table 1 and the descriptions above provide a comprehensive outline of how stakeholders interact with processing companies. This information can be collected in a similar way for other, larger organisations and for other functional areas within an organisation, such as its health and safety management or its production management systems. However, further analysis of these rankings may reveal deeper management opportunities and challenges.

2. Description of the study

The sample of the study includes interviews with the heads of 150 Russian industrial waste processing enterprises. All companies reviewed have hands-on experience with digital platforms.

The analysis included enterprises for the processing of industrial waste with more than 100 employees. Industrial waste processing enterprises continue to develop, therefore both large and small enterprises are included: construction waste processing enterprises – 9.5%; metal processing enterprises – 5.7%; chemical and mineral waste processing enterprises – 8.2%; food processing enterprises – 13.3%; others – 3.8%. All enterprises in the analysis are private companies. However, the state intervenes in the activities of these enterprises for the processing of industrial waste to a limited extent.

Fig. 1. Digital platform for industrial waste management



Source: [Borchard, Zeiss, 2021].

Table 1
Stakeholders in waste management

Stakeholders	Roles	Effects for the company
Employees	Establish and formalise industrial waste	Impact directly through work procedures
Suppliers and contractors	Provide materials and services that can guide industrial waste management practices	Direct effect, since the specification of raw materials or services may determine waste practices
Municipal authorities	Develop strategy and legislation	Local government influences the system directly through planning; monitoring and provision of waste management services. Directly affected by recovery goals and consultation process
Competitors	General customer interest. Can establish best practice	To encourage recycling businesses
Creditors, insurers and shareholders	Provide funds for insurance companies	Indirect effects such as cash receipts
Clients	Buying goods or services	Can affect the system directly
Associations and professional institutions	Creating and disseminating best practices in the industry	Influence the system indirectly through the provision of guidelines; growing interest in the sustainability of various industries
Local communities	Consumers	Influences the system indirectly through the choice of products and directly if there are local environmental problems
Non-governmental organisation (NGo)	Non-elected representation of sectors of the public	Possible indirect effects through lobbying for environmental or planning issues

Source: [Heidrich, Harvey, 2008].

Table 2
Involvement of internal stakeholders in the work of the digital platform for the disposal of industrial waste

Involvement	Stakeholder engagement, waste management (%)		The degree of interaction intencity [Knoeri et al., 2011; Asadullah, Kankanhalli, 2018]		1 – low 5 – high					Not involved
	Rank	Companies	Rank	Average	1	2	3	4	5	
Production	1	90	1	4.9	10.4	12.1	14.4	22	30.8	10
Sales department	2	85	3	4.0	9	11	16.1	20.2	28.8	15.5
Top management	3	80	2	4.7	5.1	1.5	18.8	20.4	25.8	20.5
Development research	4	70	4	3.8	8.21	9.2	12.8	19.5	20.5	31.3

Source: compiled by the author.

Table 3
Involvement of external stakeholders in the work of the digital platform for the disposal of industrial waste

Involvement	Stakeholder engagement, waste management (%)		The degree of intensity of interaction [Knoeri et al., 2011; Asadullah, Kankanhalli, 2018]		1 – law 5- high					Not involved
	Rank	Companies	Rank	Average	1	2	3	4	5	
Industrial companies – consumers of waste	5	69.2	7	2.8	11.5	12.5	13.5	15.5	29.5	31.1
Suppliers	6	65.8	5	3.5	12.3	10.3	17.5	20.3	22.3	35.2
Regional municipal government	7	60.0	6	3.1	5.8	9.3	12.2	15.2	18.2	40.2
Joint venture partners	8	55.2	8	2.6	3.2	8.3	10.5	15.2	18.2	45.8
Competitors	9	50.1	9	2.0	4.5	7.2	9.5	11.2	17.5	52.2
Consumer companies abroad	10	45	10	1.9	2.5	5.8	7.63	12.7	15.8	56.8

Source: compiled by the author.

Table 4
Involvement of internal stakeholders

Number of stakeholder involvement	Number of enterprises	Production	Sales department	Top management	Development research
0	8	—	—	—	—
1	10	2	5		3
2	13		5	4	4
3	51	13	9	15	10
4	68	68	68	68	68

Source: compiled by the author.

The annual sales volume of these companies is as follows: between 500 million and 1 billion rubles – 21.9%, from 100 to 500 million rubles – 29%, less than 100 million rubles – 17.2%. According to the evaluation criteria, 10% of these 150 industrial waste processing enterprises are in unsatisfactory economic conditions, 30.3% – satisfactory, 53.7% – good and excellent – 5%.

Section 2.3 discusses in detail stakeholders' relations in an industrial waste treatment plant. Internal stakeholders are necessary for the proper functioning and development of an organisation, while external stakeholders only indirectly influence the organisation. Companies that want to function and develop normally should focus, in addition to financial, organisational and technological aspects, on the analysis of interactions arising from the relationship between quality and stakeholders in processing companies.

In processing companies digitalisation is possible to achieve success through external stakeholders and high-quality interaction: increasing the volume of pro-consumer research (with a focus on interviews and observations), implementing loyalty programs, reducing product costs by implementing standards and minimising or eliminating defective products and complaints, improving by outsourcing activities and sales, or by taking actions that internationalise the organisation. Creating such integrated solutions for external stakeholders will have a positive effect on internal ones.

A five-point Likert scale was used to measure the intensity of interaction with internal and external stakeholders of industrial waste reuse and recycling companies and to assess the economic condition of a company by assigning companies "close to bankruptcy" and "excellent" ratings.

3. Research results

An empirical analysis of internal and external stakeholders with the largest contribution to the company is presented, out of 150 industrial waste processing companies are studied. Although the above paragraph represents a large number of stakeholders, the empirical analysis used only some of the most important stakeholders in all small and large waste management organisations.

The highest degree of involvement of processing enterprises in production (on average 4.9) and the lowest degree of involvement in development research. In terms of the intensity of interaction, the second place is occupied by the top management of enterprises, and the third place is occupied by the sales department in the production waste of enterprises.

Suppliers have the highest involvement of external stakeholders in industrial waste management, with an average score of 3.5. Consumer companies abroad are concerned about the low involvement of enterprises in waste processing. The regional municipal administration ranks second and is not yet actively involved in many waste processing enterprises. 0 to 5 for internal waste management stakeholders and 0 to 10 for external stakeholders.

Table 4 presents data that show the distribution of stakeholders into different groups depending on the number of partner groups involved in the interaction.

Table 5
Involvement of external stakeholders

Number of stakeholder involvement	Number of enterprises	Industrial companies-consumers of waste	Suppliers	Regional municipal government	Joint venture partners	Competitors	Consumer companies abroad
0	24	—	—	—	—	—	—
1	15	2	3	4	2	3	1
2	25	2	2	5	6	3	7
3	30	4	5	7	4	7	8
4	11	2	4	1	3	1	—
5	15	2	1	3	—	2	2
6	30	30	30	30	30	30	30

Source: compiled by the author.

Table 6
The relationship between the participation of internal and external stakeholders

Internal stakeholders (% of the company)	External stakeholders (% of the company)							Total
	0	1	2	3	4	5	6	
0	5.3							5.3
1	3	3.67						6.67
2	1	3	5					8.67
3	2	1	8	18	5			34
4	5	2	3.3	2	2.3	10	20	45.3
Total	16	10	16.67	20	7.3	10	20	100

Source: compiled by the author.

Top management and production occupy a major place among the external stakeholders of waste processing enterprises. In 45.5% of the companies included in the empirical analysis all groups of internal stakeholders are involved in processing and reusing industrial waste.

16% of companies do not involve external stakeholders in recycling. In 20% of the companies included in the empirical analysis, all groups of external stakeholders are involved in the process of recycling and reuse of industrial waste.

Table 6 shows the relationship between internal and external stakeholder involvement.

20% of waste management enterprises have internal and external stakeholders 5.3% of waste management enterprises have no more than one internal and external stakeholder.

4. Discussion of research results

Differences in the intensity of engagement with specific stakeholder groups were examined in table 7, using analysis of variance to identify statistical differences. Industrial waste treatment companies with good and excellent economic positions have a high level of participation as external stakeholders in the form of foreign fig suppliers. The implementation of the plans is necessary for the mutual involvement and stimulation of all internal and external stakeholders of the business.

The role of joint ventures is reduced in companies that define the economic situation as excellent, which indicates a lower intensity of the company's interactions. This research shows the growth of every internal and external stakeholder. The local government is one of the main stakeholders of the processing company. According to this rating data, production is in favor of the company's performance. These results provide insight into the company's role in terms of internal and external stakeholders, as well as the importance of stakeholder engagement

5. Practical recommendations

The main goal of stakeholders is to achieve transparency in decision-making through stakeholder participation and feedback within the company. Many waste management organisations still do not communicate openly with stakeholders. This is supported by this study, in which the failure of top managers to control stakeholders through proper communication and adequate information sharing in the early stages of projects led to project failure. An empirical analysis has been developed and results have been obtained to measure and describe the interaction of internal and external stakeholders in the waste

Table 7
Company performance and partner involvement

Company performance	Share of companies from interested parties				Interaction intensity, average					
	Unsuccessfully N = 13	satisfactorily. N = 58	Good N = 60	Excellent N = 19	Unsuccessfully N = 13	satisfactorily. N = 58	Good N = 60	Excellent N = 19	f	Static Significance
Production	56.8	84.1	75.1	81.0	2.6	2.8	3.6	4.29	3.681	0.014
Sales department	65.7	85.1	47.1	78.5	3.5	3.9	4.0	4.3	2.156	0.052
Top management	25.0	14.0	56.4	86.2	4.17	4.20	4.22	4.25	4.256	0.047
Development research	25.0	15.1	56.3	63.8	3.46	3.6	3.85	4.0	6.129	0.056
Industrial companies – consumers of waste	69.7	89.6	39.7	78.3	2.6	2.8	3.0	3.9	0.124	0.289
Suppliers	50.5	85.6	15.7	15.8	3.0	3.2	3.5	4.0	0.147	0.069
Regional municipal government	50	56.3	56.7	89.1	2.6	3.0	3.5	4.5	0.369	0.056
Joint venture partners	42.8	58.6	58.4	26.8	4.0	4.2	4.5	4.7	1.236	0.048
Competitors	47.8	96.7	23.6	56.9	3.6	3.5	3.8	3.9	2.368	0.047
Consumer companies abroad	69.3	58.1	56.9	85.6	3.8	4.0	4.5	4.8	3.562	0.082

management processes of Russian companies. While we confirmed in the previous section that many stakeholders are involved in the waste management process, it is emphasised that among the few internal and external stakeholders selected for the sample, internal stakeholders are more involved than external stakeholders. The waste management process will also be able to attract more external stakeholders through digital platforms. The results of this study suggest that the internal activities of waste processing enterprises should be strengthened with the interaction and involvement of external stakeholders. In addition, the results of this study also examined how the involvement of external and internal stakeholders affects the economic performance of a company. It is concluded that companies with high economic status have a high level of interaction between external and internal stakeholders. (e.g., foreign suppliers and government involvement). Waste recycling companies have themselves assessed their economic situation, and the increasing use of digital platforms for this could change the economic situation. In general, the extent to which the level of contact with stakeholders and the intensity of their interaction are related to company performance is examined.

Conclusion

Many businesses use digital platforms despite the quality of the work available. Since employees working on the digital platforms of recycling companies are considered self-employed, they do not have a fixed income. The lack of stable income and the lack of security offered by the platforms, as well as the lack of long-term skill development, put them in a precarious position. With regard to short-term measures that may have an immediate effect, the municipality should consider how to regulate the digital economy. In the longer term, policymakers need to think about how to prepare stakeholders for a successful decent-work negotiation. For this reason, policymakers must find a middle ground that allows stakeholders to participate in the economy by providing a social safety net that will protect them socially without diminishing the opportunities created by digital platforms. While effective implementation is yet to come, policymakers must look for creative ways to empower and protect stakeholders without impacting digital platforms.

Digitalisation is critical to help industrial waste management achieve its goals by boosting the transformation towards a sustainable circular economy by narrowing the material loops with increased resource efficiency. By fostering technological innovation in products and processes, digitalisation promotes efficient waste minimisation and longer life for products, and reduces transaction costs.

Investing in smart city initiatives can improve planning, preparation and response to global pandemics that require timely and comprehensive action.

The literature shows that digitalisation is a driving force, helping to move towards low-carbon development strategies within the circular economy.

The use of digital solutions for the recycling industry is a viable solution to strengthen the circular economy, resource-saving and low-carbon economy. In the age of Industry 4.0 digital solutions can improve waste recycling practices. With digitalisation, a proper waste management system is mandatory to protect the environment and public health.

Through digitalisation, the waste sector can contribute to the country's circular economy on the path to sustainable development. Digitalisation not only improves the management of industrial waste, but also maximises the efficiency of its use through recycling.

Waste management organisations consider the role of stakeholders as an important determinant of quality, thereby increasing the efficiency and competitiveness of the company. This ensures that the correct level of quality is achieved. It also limits the impact of internal and external conditions on the efficiency of the waste recycling process. So, one of the most important determinants of quality management and the implemented strategy of a waste processing organisation is the satisfaction of internal and external stakeholders, measured by the quality of goods and services offered by organisations. This means digitalisation, mobility, globalisation, etc.

In general, the industrial waste company confirms the goals of digitalisation, and the three most commonly expected results of digitalisation are increased process transparency, increased efficiency, and improved quality.

Improving stakeholder participation in downstream enterprises will enable enterprises to gain long-term competitive advantages. This study presents the results of a survey of 150 processing companies in Russia and analyses the interactions of external and internal stakeholders. Using data from waste management companies, internal and external stakeholders analyse how the business is driving efficiency gains. Stakeholder participation can play a mediating role in cross-functional coordination within a company, and it determines the success of external stakeholder involvement in the cross-process. This data analysis raises several questions.

1. Does the interaction between internal and external stakeholders affect the performance of the waste management company?

2. How does digitalisation affect the work of internal and external stakeholders?

3. Does a reduction in the number of partners and stakeholders in a processing company and a change in the degree of interaction mean the effectiveness of the company's economic efficiency?

The study also has limitations. First, since recycling companies are still growing in Russia, this study was conducted by collecting data from not only large companies but also small recycling companies. Although these companies have different stakeholders, a random number of stakeholders were selected for the sampling. The study provides an overview of the contribution of digital platforms to waste management as well as the internal and external stakeholders of waste management companies.

References

Asadullah A., Kankanhalli A. (2018). Digital platforms: A review and future directions. *Management Science,* 1: 50-60.

Berg H., Wilts H. (2019). Digital platforms as market places for the circular economy. *Nachhaltigkeits Management Forum,* 27: 1-9.

Bonina C., Koskinen K., Eaton B., Gawer A. (2021). Digital platforms for development. *Development in the Information Systems Journal,* 31(6): 1-12.

Borchard R., Zeiss R. (2021). Digitalisation of waste management: Insights from German private and public waste management firms. *Waste Management & Research,* 40(6): 776-794.

Cane M., Parra C. (2020). Digital platforms: Mapping the territory of new technologies to fight food waste. *British Food Journal,* 122: 359-369.

Cremona L., Lin T. (2014). The role of digital platforms in interfirm collaboration. *Organisation and Management*, 10(2): 1029-1040.

Heidrich O., Harvey J. (2008). Stakeholder analysis for industrial waste management systems. *Waste Management,* 29: 965-973.

Jingyi Wang, Tao Bai (2021). How digitalisation affects the effectiveness of turnaround actions for firms in decline. *Long Range Planning,* 20: 10-25.

Kintscher L., Lawrenz S., Poschmann H. (2020). Recycling 4.0 - Digitalisation as a key for the advanced circular economy. *Journal of Communications,* 15(9): 652-660.

Knoeri C., Binder C., Althaus H.-J. (2011). Construction stakeholders' decisions regarding recycled mineral construction materials. Resources, *Conservation and Recycling,* 55(11): 1039-1050.

Kojima M. (2008). Stakeholders' relationships in the recycling systems. Experiences in the Philippines and Japan. *The International Journal of Life Cycle Assessment,* 15: 81-109.

Kovacic I., Honic M., Sreckovic M. (2020). Digital platform for circular economy in AEC industry. *Engineering Project Organisation,* 9: 56-66.

Neves da Rocha F., Pollock N. (2019). Innovating in digital platforms: An integrative approach. *Management Science,* 23: 30-40.

Rochet J.-C., Tirole J. (2003). Platform competition in two-sided markets. *European Economic Association,* 5: 3030-3040.

Schmalensee R. (2014). An instant classic: Rochet & Tirole, Platform competition in two-sided markets. *Economics and the Entrepreneurship,* 10(2): 1029-1040.

Tambouris E., Migotzidou A. (2015). E-consultation platforms: Generating or just recycling ideas? *Electronic Participation*, 3: 41-52.

Tiwana A., Ramesh B. (2001). E-services: Problems, opportunities, and digital platforms. *Strategic Management Journal,* 5: 821-831.

Xiaodong Zhu, Wei Li (2021). Research on the pricing strategy of "Internet+" recycling platforms in a two-sided network environment. *Sustainability,* 12(3): 1111-1125.

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