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UDK 625.1

Robotic Transport Platform for Forestry

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Key words and phrases: robot; robotic platform; forestry; transport.

Abstract. The goal is to develop a transport platform for forestry that reduces the share of heavy and monotonous manual labor of workers. The tasks are to study the working conditions and technical requirements for the transport platform and development of a prototype of its design. To achieve this goal, the method of system analysis and the method of functional-structural-technological analysis were used. In the course of the study, a three-dimensional model of the prototype of the transport platform was developed.

At present, robotic solutions are being actively introduced in various sectors of the national economy to ensure the automation of transport operations.

In Russia and abroad, research and development work is actively carried out, as well as trial operation of robots operating in closed areas: in quarries of mining enterprises, fields in agriculture, etc. There are no pedestrians and third-party objects in the closed territories, the number of other robotic platforms on the territory and their position at each moment of time are known in advance, the route of movement is clearly established. Autonomous mining dump trucks are used in many countries, at some enterprises such solutions have been in trial operation for more than ten years, a number of projects have successfully moved to the stage of commercial operation [1]. Control systems for unmanned agricultural machinery are being actively developed and introduced into trial operation, including in Russia [2]. Such solutions can be either remote (the operator controls all work from a remote workplace) or completely autonomous (the operator only controls the operation of equipment that works independently).

At present, the share of manual labor in forestry is still very high. Heavy manual labor can be replaced by using modern specialized robots in labor-intensive operations [3]. Works in forestry are associated with tasks that require the movement of cargo, tools and personnel from a dirt road over rough terrain and cutting to the place of forestry or firefighting work and back, creating a stock and moving planting material and tools to the landing site; movement of workers, PPE, tools (motor brush cutters, chainsaws, sprayers) and fuel; moving small-sized wood raw materials in the immersed state; movement of motor pumps, hoses and fire nozzles, water supply and tools in the fight against fires; movement of non-timber forest products, etc.

When working in forest and ornamental nurseries, it is also necessary to solve the problem of moving certain goods across the territory with previously known routes. In addition, in the nursery, the platform can solve some tasks related to caring for plants when equipped with

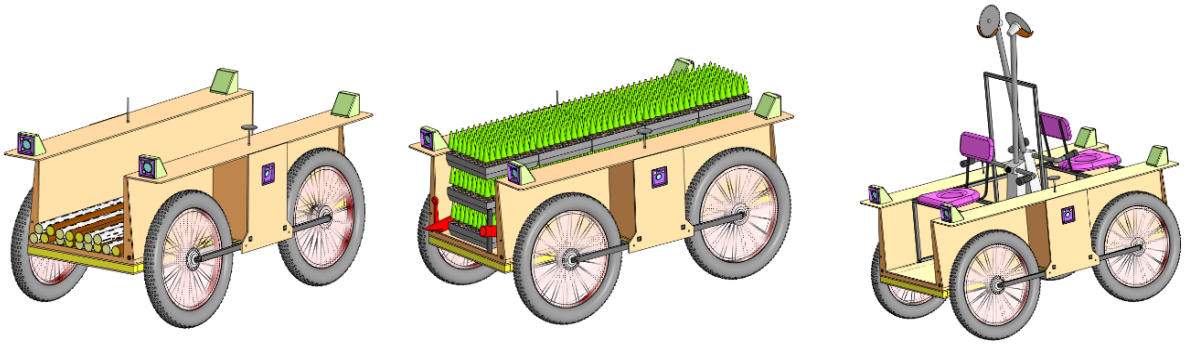

Fig. 1. Platform prototype

appropriate equipment: watering, fertilizing, etc.

In order to classify and streamline the information collected in relation to the issue under consideration, its system analysis was carried out. The results of the system analysis served as the initial data for the next stage of the functional-structural-technological analysis, during which the basic requirements for the robotic transport platform were established, taking into account its purpose for use in forestry, and certain design and technological solutions were proposed.

The platform should be relatively inexpensive and light, this requirement is met by the option of building a platform based on a 4 × 4 wheel arrangement. The wheel mover and the use of motor-wheels will not only simplify, lighten and reduce the cost of the structure, but also increase the autonomy and speed of the platform movement. In the design of the prototype, it is proposed to use an electric drive. A prototype of such a platform is shown in Fig. 1.

The task of independent safe movement of the robot from one point of space to another over rough terrain avoiding stationary and dynamic obstacles without the help of an operator is extremely difficult. The robot must build its own trajectory of movement, using the data about its position, the position of stationary obstacles and the prediction of the position of dynamic obstacles. Modern robots use various methods of localization in space and detection of obstacles, for which satellite navigation, computer vision, lidars and other sensor systems are used. Although the software and hardware of modern robots is rapidly evolving and becoming noticeably more complex, there are no ready-made solutions to such complex problems yet.

However, to solve transport problems in forestry, the prototype forestry transport platform may not be completely autonomous and work according to simpler algorithms. So from the start point of the route to the end point of the route, the platform can be moved with the help of an operator using remote control from the remote control or using the “follow a person” function, that is, the robot will move strictly along the operator’s trajectory, following from him at some distance. The route and obstacles on the trajectory in the direction of travel will be fixed by the prototype using satellite navigation and data from its sensors. In the future, the prototype will be able to return to the starting point of the route on its own, using the collected data about the route and obstacles on it when moving. When moving independently, the robot will use its sensors to detect new (unknown) obstacles on the route. If new obstacles are found on the route, the platform will have to stop and request remote assistance from the operator, who will have to remotely help the robot pass through a difficult place using the remote control, using information from video cameras on the prototype.

Currently, Petrozavodsk State University is working on a project of a transport platform for forestry, which is under development of the technical part, it is planned to build an experimental

model to test the patency of a wheeled platform on the ground and use it as a base for testing control systems.

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Транспортная платформа для лесного хозяйства

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Ключевые слова и фразы: лесное хозяйство; робот; роботизированная платформа; транспорт.

Аннотация. Цель – разработка транспортной платформы для лесного хозяйства, обеспечивающей снижение доли тяжелого и монотонного ручного труда работников. Задачи: изучение условий работы и технических требований к транспортной платформе и разработка прототипа ее конструкции. В ходе проделанной работы разработана трехмерная модель прототипа транспортной платформы.

UDK 630

Protection of Linear Facilities Passing through Forest Territories

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Key words and phrases: linear facilities; protection of linear facilities; woody vegetation; forest fire.

Abstract. The goal is to analyze the technical characteristics of linear facilities passing through the territory of the Republic of Karelia and requiring protection from especially dangerous woody vegetation. The research tasks are to determine the main danger, impact during the operation of linear facilities passing through the territory of the Republic of Karelia. In the course of the work, the analysis method was used, during which a special topic of scientific and technical information was collected with its generalization and systematization. The result is as follows: in the course of the work done the main types and length of linear facilities passing through the territory of the Republic of Karelia and requiring protection from special woody vegetation.

Roads and railways, inland waterways, tram lines, power lines, communication lines, pipelines (including gas pipelines, oil pipelines) and other similar structures, the length of which is much greater than the width, are linear facilities.

As a result of various factors, such as violation of construction requirements, factory defects in equipment and materials, violation of technological regulations during the operation of linear facilities, natural hazards and the interaction of technological elements of linear facilities with the natural environment, the human factor, emergencies and man-made disasters arise.

At linear facilities, the main hazards that can lead to emergencies and man-made disasters include:

– technogienic hazards;
– anthropogenic hazards;
– natural hazards.

Technogenic hazards include hazards associated with the operation of linear facilities, using combustible, flammable and explosive substances and materials, using processes that occur at elevated temperatures and high pressures, using electrical energy, etc.

Anthropogenic hazards include hazards or negative factors that are formed as a result of human impact on the safety of operation of linear facilities. The factors causing anthropogenic dangers are the organizational and psychological aspects of human activity (human factor, fatigue, stress, terrorist act, etc.).

Natural hazards include hazards or events of natural origin, as well as the result of natural

processes, which, by their intensity, scale of distribution and duration, can cause a damaging effect on the safety of linear facilities. At the same time, vegetation, like relief and soil moisture, also affects the condition and safe operation of linear facilities.

The analysis of the data [1] made it possible to establish the extent of linear facilities on the territory of the Republic of Karelia. The length of the network of motor roads of regional significance of the Republic of Karelia is 6038 km. The structure of the network of regional highways by types of coverage is presented as follows: with asphalt concrete pavement – 1,751 km; with sand-gravel-crushed stone coating – 2,653 km; uncoated (unpaved) – 1,634 km. The length of the network of federal highways passing through the territory of the Republic of Karelia is 1,709 km.

The total length of railway lines in the region is 2,669 km. Additionally, along with the railway tracks, contact networks of auxiliary equipment, high-voltage and low-voltage power lines are laid, which also require maintenance and clearing of unwanted woody vegetation.

As for energy facilities, the length of 6–10 kV transmission lines is 5,948 km along the route, 35–110 kV transmission lines is 4,717 km along the route and 220–330 kV transmission lines is 1,874 km along the route.

Almost all components of the gas transmission system carry a potential hazard. The total length of the gas transmission system is about 820 km, which includes gas pipelines-outlets, inter-settlement gas pipelines and gas pipelines-inlets with gas distribution networks [2].

As a result of the analysis, it was found that the total length of linear facilities requiring protection from unwanted tree vegetation and forest fires on the territory of the Republic of Karelia is 23,775 km.

In the course of the study, it was found that the main violations of fire safety requirements are associated with the lack of fire-prevention distances to forests; not ensuring the cleaning of the territories adjacent to the forest from dry vegetation and debris; the absence of a mineralized strip on the border of the facility with the forest area.

To protect linear facilities from man-made and natural hazards, linear facilities passing through forest areas should be cleared of unwanted woody vegetation in a timely manner. These works can be carried out both manually using a motorized tool, and using special equipment. At the same time, it must be taken into account that the work must be carried out in such a way that the cut woody vegetation does not create a fire hazard.

Knowledge of the types of linear facilities, their geographical location, length, will allow for systematic planning of these works, taking into account the specific features of linear facilities, the features of the terrain along which they pass, the growth rate of woody vegetation in a particular area, the equipment available to the contractor. Since it is necessary to use highly specialized equipment to clear linear facilities from unwanted vegetation, the systematization of this type of work, taking into account the type of linear facilties, its length will allow rationally planning the volume and time of work, choosing rational technological processes, taking into account the profitability of involving cut vegetation in the processing, which will reduce costs due to the rational logistics organization of this process.

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Защита линейных объектов, проходящих по лесным территориям

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Ключевые слова и фразы: древесная растительность; защита линейных объектов; лесной пожар; линейный объект.

Аннотация. Цель – выполнить анализ технических характеристик линейных объектов, проходящих по территории Республики Карелия и требующих защиты от нежелательной древесной растительности. Задача: определить основные опасности, возникающие при эксплуатации линейных объектов, проходящих по территории Республики Карелия. В ходе работы использовался метод анализа, при котором осуществлялся сбор соответствующей теме научно-технической информации с ее обобщением и систематизацией. В ходе проделанной работы определены основные виды и протяженность линейных объектов, проходящих по территории Республики Карелия и требующих защиты от нежелательной древесной растительности.

UDK 004.9

Methodological Approaches to Lean Digitalization

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Key words and phrases: lean digitalization; organizational systems; life cycles; maturity levels; lean ideology.

Abstract. The article describes a new angle of using lean ideology for deploying the processes of digital transformation of organizational systems and value creation life cycles, specifies some features of perception of the maturity level of basic processes and measures of their readiness to change. A description of the documentary basis for formalizing the process of transition to a new technological concept of digital transformation is formed, and the normative legal documents regulating the content of the national program “Digital Economy of the Russian Federation” are described. The article presents possible approaches to leveling the analyzed problems in change management processes and internal conflicts of organizational systems with the help of lean digital transformation tools.

Trends in the digital transformation of organizational systems are now widely popular. Dynamism and uncertainty make it necessary to work on the costs of core processes, putting more and more effort into developing or finding new effective tools to improve efficiency.

The current paradigm shift from automation and informatization of production and technological processes to the so-called digitalization can be seen as a sought-after innovative behavior that can lead to qualitative changes in production systems.

Despite the stated positive points in the development of digitalization in Russia, it should be noted the potential contradiction between the course on the accelerated implementation of digital technology and the maturity of the business processes of the digital enterprise, which contains quite high project risks

Production-economic and situational-technical problems solved by organizational systems built on mechanical principles generate enough information to create a knowledge base and initiate change management processes to stop or reduce to an acceptable minimum emerging errors and inconsistencies in production and technological processes.

However, the ongoing organizational and technical solutions for leveling the main problems arising in the production systems face the settled corporate culture built on the principles of X&Y McGregor’s theory, where depending on the behavioral model of the personnel different management utilities are used. Consequently, most of the changes will be perceived by staff

as the implementation of the negative model of the theory of McGregor. Thus, a stable image is formed of a traditional vertical organizational structure really capable of resilience to external challenges, but poorly functional in the processes of accumulation and synthesis of new tools and solutions in cases of iterative typical problems or formation of new non-typical challenges.

Digital transformation creates prerequisites for the change of organizational models of mass manual production systems in serial and large-scale production of mechanized or highly automated technological processes. In some branches of industrial production sector the replacement of flow personnel with highly qualified personnel able to service automated complex technical systems and complexes is observed. Processes of migration of personnel potential as a whole on branch or in adjacent branch spheres is a trend of the present time. However, the processes of personnel migration entail a crisis in the systems of organizational knowledge management. The accumulated formal and informal knowledge of processes and technologies forms the core of organizational systems and allows the accumulation of sufficient information to create a knowledge base, the reference to which increases the effectiveness of change management processes in relation to external challenges. Consequently, a consistent policy in the development of corporate culture and the perception of personnel as a source of organizational knowledge necessary for the integration of digital technologies in all processes of the life cycle of production systems is necessary.

Under the influence of digital transformation processes, it is likely that the restoration of legacy technologies, elements of which were once popularized and selectively used by meaningful leaders in functional organizational systems, will be embraced as a modern and effective tool for achieving the goals of a cost-saving strategy. An image of an interesting solution is the proposal to consider the life cycles of production systems through lean ideology.

Problems of integration of lean production concepts into technological processes and in processes of management of organizational systems have emerged since the collision between lean ideology belt holders and leaders of technological changes guided by PMBoK project management principles.

Based on the above, a synergistic approach to digitalization, based on the basic principles of lean production and modern project management, hereinafter referred to as “lean digitalization”, is proposed. Thus, lean digitalization should be understood as a process of organizing the performance in a digital environment of functions and activities (business processes), previously performed by people and organizations without the use of digital products, based on the principles of lean production [6] and implemented in accordance with the principles of project management [5].

The complex and complex task of implementing modern change management concepts can also rely on modified traditional tools widely proven in practice, used fully enough to deploy new processes and improve current ones - with minimal costs for their application, such as the cycle “PDCA – SDCA”. Iteratively using the cycle “PDCA – SDCA” and SMART is possible to achieve a synergistic effect in the modernization of technological processes or use as a tool for controlling the processes of digital transformation [7] in manufacturing systems.

Application of digital technologies for lean lifecycles will allow avoiding technological and documentary audits causing a certain measure of distrust of the inspected personnel, especially if the procedure of internal audit is initiated by neighboring structural divisions. The resistance of the personnel to the researches can be effectively represented through falsification of statistical data on technological processes, changed metrics on the workplace output, meeting or not meeting the standards, or internal normative quotas on productivity and production discipline. Process research using traditional auditing techniques and process timing of work operations

Table 1. Characteristic problems for organizational systems and solutions offered by different methodologies

№	Problems	Production organization	Lean ideology	Digital transformation [9]
1	Complex-structured view of the process of dispatching the capacity of the production system	Development of a model for calculating capacity utilization of the production system using existing resources of process owners	Use of process audits, application of tools such as process timing, spaghetti diagram, meande-mapping	Smart Manufacturing technologies, computer vision for process timing
2	Lack of visualization of the procurement process control from the outgoing application of the structural unit from the customer procurement process	The problem is solved by developing and implementing the SIPOC form and identifying customer requirements to the manufacturer and customer requirements to the supplier through a decision chart	It is also advisable to solve this problem by introducing visualization methods and kanban cards	Recommendation systems and intelligent decision support systems, dashboards for departments that form equipment applications
3	Excessive centralization and scaling of administrative and managerial staff, chronic time constraints for the organization	Lack of a system of periodic monitoring of the effectiveness of personnel, certification activities, audit of individual goal-setting	Additional tool to identify intellectual potential through mind maps, the formation of KPI for processes [10]	Remote centralization of managerial staff through the use of VR/AR content and technology of visual presence
4	Increased time interval between the beginning and the end of the basic and auxiliary processes of the production system	Error in the planning stage of the life cycle can be solved by implementing risk diagrams in the process technology and its documentation, conducting FMEA-analysis and implementation of GOST R ISO 31000-2019	SMED, Development of value stream maps, conducting technology audits, reviewing digital quotas	Motion capture technology in VR/AR and photogrammetry, mathematical modeling and product lifecycle management (Smart Design)
5	Lack of vision of the model of physical flow of technological operations	Lack of systematic audits for iterative actualization of NTD characterizing performance processes	Standard operations maps, spaghetti diagrams, VSM maps	Standard operations maps, spaghetti diagrams, VSM maps Digital twins of technological operations, platform solutions for users: editors of content creation and distribution [11]
6	Lack of information on the practical application and morphology of BP tools, TQM	One-time solution by a one-time intervention in a functional structural model in order to impose another method of work	Multilevel and systematic auditing iterative application of 5S methods in order to merge lean ideology with daily routine processes that create organizational value	The use of VR/AR technology in industrial enterprises plays an important role creating versatile tools for creating, editing and delivering content in VR/AR, including libraries of templates and digital objects

Table 1. Characteristic problems for organizational systems and solutions offered by different methodologies

№	Problems	Production organization	Lean ideology	Digital transformation [9]
7	Current corporate management culture corresponds to the industrial stage of development	Complex imperative hierarchical production system based on the realization of the organization's function and support of its existence on the market	Product organizational systems structured according to the principles of rapid life cycle oriented to the realization and promotion of the own manufactured product with an iterative audit of the value created	Feedback interfaces and sensors for VR/AR used by all personnel without status restrictions, speech recognition and synthesis
8	Incompleteness of the design and technological preparation of production	Lack or incompleteness of functionality of existing models of dispatching of capacity utilization at unpredictable rhythm of market environment demands, incompleteness of the influence of the existing ERP system on the basic processes of value creation	Predictive management based on OEE methodology in combination with TPM technology and resource allocation for integration team, developed recommendations for process improvement	Semantic enterprise search engines, document classifiers, speech recognizers and conversational AI agents. Data organization and synchronization technologies
9	Bureaucratic discrepancy between the requirements of normative and technical documents and regulating activities in the same production chain	Traditional organization of functional structures according to the "struggle of departments" principle, lack of a unified policy and mechanism of documentation actualization and unification	Leveling of process barriers by relocating administrative and management personnel into a common space with minimized travel distances between them, based on a “one office” approach	Feedback interfaces and sensors for VR/AR used by all personnel without status restrictions, speech recognition and synthesis, Semantic Enterprise Search Engines, document classifiers
10	Lack of perception of internal suppliers as participants of lifecycle systems	The focus on the internal consumer means not only a fundamental role in the system, but also getting reliable information about the needs and wishes of the consumer, which will allow to increase production capacity in the stages of lifecycle, creating value	To maximally simplify the form for the creation of records for visualization of the value creation process which includes all participants of the life cycle	Technologies to ensure data integrity and consistency (consensus)

can take on the nature of unpopular measures of production systems research among both line personnel and the substantive leaders of organizational systems.

Reduction of influence of factors on technological processes can be reached either by development of point recommendations and address decisions, but also by introduction of elements of various methodologies, not excluding problems arising at their deployment. The existing actual list of problems to be considered for the research of the reasons of partial realization of elements of lean technologies and how the transition to the digital era in production will help to fully create digital lean lifecycles for production systems is presented in table 1.

Thus, the transition to digital transformation will allow restoring the processes of integration

of lean ideology into the life cycles of production systems. Research and development processes with implemented digital lean lifecycles will allow to respond promptly to market changes and to transfer conditional serial production systems to large-individual orders. The transfer of GOST 2.116 requirements to digital platforms and information integration with the FIPS data bank will increase the efficiency of processes of analysis of technical novelty and practical significance of the product being developed or already produced.

The transition to digital quality processes, to digital processes of monitoring of technological operations are new solutions for the new digital economy, and the present article can be a convenient methodological material in decision-making processes for the implementation of lean digitalization in the life cycles of production systems.

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Методологические подходы к бережливой цифровизации

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Ключевые слова и фразы: бережливая идеология; бережливая цифровизация; жиз-

ненные циклы; организационные системы; уровни зрелости.

Аннотация. В статье описан новый ракурс использования бережливой идеологии для развертывания процессов цифровой трансформации организационных систем и жизненных циклов создания ценности, уточнены некоторые особенности восприятия уровня зрелости основных процессов и меры их готовности к изменениям. Сформировано описание документарного основания для осуществления формализации процесса перехода на новую технологическую концепцию цифровой трансформации, описаны нормативно-правовые документы, регламентирующие содержание национальной программы «Цифровая экономика Российской Федерации». В статье представлены возможные подходы к нивелированию проанализированных проблем в процессах управления изменениями и внутренних конфликтах организационных систем с помощью инструментов бережливой цифровой трансформации.

UDK 372.882

Communicative Competence in its General Competence Characteristics

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Key words and phrases: communicative competence; competency; linguistic competence; sociolinguistic competence; discursive competence; strategic competence; sociocultutal competence; social competence; foreign language proficiency; autonomy of the student; competence-based education.

Abstract. In recent decades, the problem of human competencies / competence as the ability to successfully and efficiently solve any problems has attracted increasing attention of the world scientific and pedagogical community. To achieve the goal of the study, the following methods were used: the bibliographic method of studying normative documents and scientific and methodological literature, the analysis of foreign language competencies, the possession of which is the goal of learning foreign languages at the university, the method of monitoring the educational activities of students. It is competence in the interpretation, considered as an internal potential cognitive formation for the formation of competence as an actualized, integrative, intellectually and socio-culturally conditioned personal quality, manifested in human activity, behavior and interaction with other people in the process of solving various problems. Concluding the consideration of communicative competence in its general competence characteristics, it should be noted that, along with what it has in common with other social key competencies, it is characterized by a special specificity. This determines the peculiarities of its ontogenetic formation in the native language and the difficulties of learning in the second non-native.

Communicative competence is one of the main key competencies studied in recent decades. Naturally, along with its great elaboration by linguodidacts (N. Chomsky, D. Hymes, S. Savignon, L. Bachman, I.L. Bim, V.V. Safonova, etc.), it “requires” a generally competent psychological didactic presentation.

Back in 1979, J. Van Eck and J. Trim, the developers of the model of educational goals in the field of foreign languages for the European-wide project, noted that they and other

participants were faced with the task of creating a detailed model of educational goals that would take into account the individual development of the student as a participant in communication [10, p. 252]. Van Ek 1986 [9, p. 87] proposed the following competence components of what he called “communicative ability”: linguistic competence, sociolinguistic competence, discursive competence, strategic competence, sociocultural and social competence.

Linguistic competence is “the ability to generate and interpret sentences endowed with meaning, which are formed in accordance with the rules of the language used and have a traditional meaning for them” [11, p. 252].

Sociolinguistic competence correlates with the student’s understanding of “how the choice of language forms (mode of expression) is determined by such conditions as place, relationships between communication partners, communicative intention, and more” [14, p. 35].

The fundamental difference between linguistic and sociolinguistic competencies lies along the axis “linguistic form – language signal/meaning – meaning”. Linguistic competence includes the relationship between linguistic meanings and their traditional meaning, that is, what they mean in isolation, out of context, while sociolinguistic competence encompasses the relationships between linguistic meanings and their contextual or situational meanings.

Strategic competence reveals itself in those cases when the student is faced with the need to “convey the meaning” or “understand what the communication partners mean, that is, this competence is communication strategies, such as paraphrasing what was said or questions in order to understand the content” [13, p. 252].

Sociocultural competence implies knowledge of the sociocultural context of the use of the language being studied, which may differ in some aspects from the sociocultural context of the native language [11, p. 31]. It is important that the author includes other phenomena in sociocultural competence, such as “positive attitude, tolerance, empathy, recognition of the potential value of different thinking and different ways of behaving” [12, p. 50], and notes that the formation of a student’s sociocultural competence extends beyond the cognitive sphere and correlates with his attitude, views, value system and emotions. Social competence [6, p. 57] includes the desire and ability to interact with others.

In recent decades, the problem of human competencies/competence as the ability to successfully and efficiently solve any problems has attracted increasing attention of the world scientific and pedagogical community [8, p. 251], Tuning Project (2001–2003) [5]. Within the framework of such projects, the conceptual content of various competencies, their set, classification grounds, assessment criteria are determined, their formation and development. Competencies become the content of education, which is defined as education based on competencies. At the same time, we note that, despite the existence in the English language of two related concepts “competence” and “competency” [2], in research and publications, the term competence is mainly used. At the same time, all researchers note a different scope of the content of concepts in their description. This is also evidenced by the allocation of key competencies as broader and generalizing concepts. This feature is also fixed in the translation of English-language publications, where the term “competence” is used. In Russian, in most cases, this term is translated as competence [11, p. 394].

The activity approach as a whole determines the definition of the goal of schooling “as the formation of learning skills, as competencies that ensure the mastery of new competencies” [12, p. 17]

Initially, the need to form in the process of preparing students not only knowledge and skills, but also competencies in addition to them was recorded (Bern Symposium of the Council of Europe 1996, Tuning Project 2001–2003, etc.) At the same time, competencies in this context

were understood (J. Raven, 1984) up to 40 different qualities, characteristics of a person, his activities (motivation, interactivity, responsibility, independence, analytics, etc.) [14, p. 394].

Further, this set, denoted by the term “competencies”, is differentiated, in turn, into other, different competencies: universal (general cultural), general professional and social competencies with their descriptors “knowledge”, “ability”, “skills”. Because of this, there was a unification and absolutization of the concept of “competence” in the general context of the interpretation of the competency-based approach as a result-targeted basis for the development and formation of multi-level and multi-order competencies. Within the framework of this approach, the purpose and result of education are defined in terms of competencies.

The first direction of interpretation of the concept of “competence” is actually pedagogical. In the report of the International Commission on Education for the 21st century “Education: a hidden treasure” Jacques Delors formulated “four pillars on which education is based: learning to know, learning to do, learning to live together, learning to live” [9]. J. Delors defined the main global competencies in terms of competencies.

In the same year, at a symposium in Bern (March 27–30, 1996) on the program of the Council of Europe, the question was raised that it is essential for education reforms to identify key competencies that students must acquire for successful work. In the summary report, it was noted that the very concept of “competence”, being included in a number of such concepts as skills, competence, competency, ability, mastery, has not yet been precisely defined in terms of content. Nevertheless, as the speaker noted, all researchers agree that the concept of “competence” is closer to the conceptual field of “know how” than to the field of “know what”. Following N. Chomsky, the speaker emphasizes “that use is competence in action”.

The definition adopted by the Council of Europe of the five key competencies with which “young Europeans should be equipped” is given. These are:

1) “political and social competencies, such as the ability to accept responsibility, participate in group decision-making;

2) competencies related to life in a multicultural society;

3) competencies related to the mastery of oral and written communication, which are especially important for work and social life, with an emphasis on the fact that those people who do not master them are threatened by social exclusion;

4) competencies associated with the increase in the informatization of society;

5) the ability to learn throughout life as the basis for lifelong learning in the context of both personal-professional and social life.

In the context of this pedagogical direction, the appearance of the work of V.A. Bolotov, V.V. Serikov “Competence-based model: from idea to educational program” (2003) [2, p. 8–14]. This work notes the crisis of the knowledge-enlightenment paradigm of education and the readiness for its change by the works of V.V. Davydov, L.V. Zankov, M.S. Kogan, V.V. Kraevsky, V.S. Lednev, I.Ya. Lerner and others. According to the authors, the competence-based approach “reflects a type of educational content that is not reduced to a knowledge-oriented component, but involves a holistic experience in solving life problems, performing key (i.e., related to many social spheres) functions, social roles, competencies” [3, p. 10].

Within the framework of the psychological direction of the interpretation of the concept of “competence”, the list of competencies as conditions for the success of an activity is significantly expanding. In the work of J. Raven (Eng. 1984), about forty types or components of competence are defined that ensure the success of training and activity [2, p. 281–297]. Among them are self-confidence, using feedback, self-control, critical thinking, decision-making ability, perseverance, personal responsibility, the ability to listen to other people and take into account what they say.

The interpretation of the component composition of the content of competence also correlates with its definition proposed by the authors of the "Strategy for Modernizing the Content of General Education". According to this definition of competence, "this concept is broader than the concept of knowledge, or skills, or habits, it includes them".

It is important to note that competence is an integrative personal quality manifested in activity, in solving various social and professional tasks by a person.

Concluding a general description of competence as an integrative education, which includes many different competencies, we note that in most publications, the authors refer to one term as competence and global, which combines particular phenomena into a concept, and each of them separately. A clear distinction between the concepts of "competence" and "competency" removes this ambiguity.

This most important distinguishing feature is that the formation of a child's communicative competence initially begins from the first days of his life and continues until its end. The communicative-cognitive activity of a child, family communication, education are determined on the basis of innate language ability as the process of formation of communicative competence, and its result, its quality.

This feature of communicative competence, which distinguishes it from other key competencies, was noted in terms of language features by W. Humboldt, N. Chomsky. According to N. Chomsky, there is some real opportunity to study thinking for perception and the innate basis for language acquisition [4, p. 115].

However, in the structure of communicative competence, these components have a specific content. Let's take this as an example of speaking. The competence content of its structure is as follows: the first component is knowledge. The "knowledge" component in communicative competence is a multifaceted content that is formed throughout life. First of all, it is knowledge of the situation of communication, which determines the style and genre of this process. This is due to the fact that knowledge of the situation includes knowledge and, accordingly, understanding of positional role relations in which a person realizes his communicative competence. Knowledge of the situation of communication includes orientation in the interlocutor, knowledge and observance of traditions, etiquette – in general, the culture of communication.

Concluding the consideration of communicative competence in its general competence characteristic, we note that, along with what it has in common with other social key competencies, it is characterized by a special specificity.

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Коммуникативная компетентность в ее общекомпетентностной характеристике

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Ключевые слова и фразы: владение иностранным языком; коммуникативная компетенция; компетентностное обучение; компетентность; лингвистическая компетенция; социолингвистическая компетенция; самостоятельность обучающегося; социальная компетенция.

Аннотация. В последние десятилетия проблема компетенций/компетентности человека как способности успешно и эффективно решать любые задачи привлекает все большее внимание мирового научно-педагогического сообщества. Для достижения цели исследования использовались следующие методы: библиографический метод изучения нормативных документов и научно-методической литературы, анализ иноязычных компетенций, владение которыми является целью изучения иностранных языков в вузе, метод контроля учебной деятельности студентов. Именно компетентность, рассматриваемая в интерпретации как внутреннее потенциальное познавательное образование, которое затем актуализируется в деятельности, понимается как предпосылка и основа формирования компетентности как актуализированной, интегративной, знаниевой, интеллектуально и социокультурно обусловленной, личностное качество, проявляющееся в деятельности человека, поведении и взаимодействии с другими людьми в процессе решения различных задач. Заканчивая рассмотрение коммуникативной компетентности в ее общекомпетент-

ностных характеристиках, следует отметить, что наряду с тем, что она имеет много общего с другими ключевыми социальными компетенциями, она характеризуется особой спецификой. Это определяет особенности ее онтогенетического становления на родном языке и трудности обучения на втором, неродном языке.

UDK 334.72

Analysis of the State and Problems of Development of Small Business in Modern Conditions (Using the Example of the Tambov Region)

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Key words and phrases: entrepreneurship; entrepreneurial activity; small businesses; external and internal risks; entrepreneurial initiatives; regional programs.

Abstract. The purpose of this study is to analyze and identify the problems of small business development in the Tambov region in modern conditions. The objective of the study is to analyze the current state of small business in the Tambov region, as well as possible risks in modern conditions.

The main hypothesis of the study is that the pandemic has significantly affected the development of small businesses in the region, which led to a reduction in the number of small businesses. The research methodology is scientific search, generalization, analysis, systematization. The results of the study showed that the 2019 pandemic led to a reduction in the number of small businesses, but practice shows that in the current crisis conditions, it is necessary to quickly adapt your plans. Modern realities require not only the adoption of anti-crisis measures, but also the introduction of a flexible business organization system, as well as support for entrepreneurial initiatives and regional programs for the development of small businesses.

Entrepreneurial activity is always a risk, because the entrepreneur has no guarantees that his/her product will be sold in full. Any entrepreneur, regardless of the area, faces many problems: imperfections in tax legislation, unfair competition, high interest rates on bank loans, and lack of economic resources. But in addition to the above reasons, the state of affairs and the further development of small businesses were complicated by the COVID-19 outbreak that occurred in December 2019. The number of cases per day has grown at a rapid pace. The WHO has declared a worldwide pandemic. After the regions were forced to go into a total self-isolation regime after Moscow, representatives of small businesses suffered the main financial blow from the pandemic: beauty salons, clothing stores, hairdressers, manicure parlors and many organizations in other fields of activity. The reduction in revenue in the Tambov region amounted to more than 80 % for small businesses.

Most businessmen at the initial stage outbreak of the COVID-19 did not perceive it as a serious and impending threat, and only after the official ban on economic activity, entrepreneurs realized what losses they would incur. But it was simply impossible to stay away from losses. At the first stages, the state tried to provide assistance to small businesses in the form of funds for the payment of wages to employees, but this did not last long, after which the business had to cope on its own.

But even if the assistance in the form of funds for wages from the state continued, this would not save small businesses, since they did not have the funds to purchase raw materials and provide work. Therefore, wages were a small part of the costs incurred by entrepreneurs. It was this fact that caused such a decrease, which ultimately led to the abrupt closure of a huge number of organizations and individual entrepreneurs, because their work became inappropriate.

Today, the risk for the entrepreneur is everywhere. No matter how competently a business entity conducts business and controls all processes, there are always risks. A good example is the pandemic, because no one could even imagine that this would happen. In this regard, there is no way to fully achieve the economic security of management. The task of small businesses is to minimize risks, thereby guaranteeing a stable dynamics of the transformation of their own business structures, practically eliminating the likelihood of “shocks”.

The subjects of small business are small enterprises, micro-enterprises, and medium-sized enterprises. To study the state of small business, official statistics will be used, located on the website of Federal State Statistics Service, as well as information on SMEs, which is posted by the Federal Tax Service.

The Tambov Region is a constituent entity of the Russian Federation and is part of the Central Federal District. The region has a favorable geographical position, which contributes to the development of the economy in the region. The leading positions in this industry are occupied by: chemical production, production of electrical equipment, production of equipment for industrial enterprises, light industry. The specificity and importance of industrial production in the Tambov region is largely determined by manufacturing industries. The largest share in the structure of industrial production falls precisely on the types of activities of manufacturing industries. In the Tambov region, the agro-industrial complex is dynamically developing, which is a vector of development and remains one of the priority areas for the region’s economy, since exports depend on it, private investments and funds from various state programs are actively invested in it. Also, the region has a significant scientific potential, the necessary resources for the implementation and development of scientific and technical activities. The Council of Young Scientists and Specialists is working effectively on the territory of the region, various initiative projects are being implemented, the main purpose of which is to search for innovative priorities for the development of the economy.

Based on the official statistics of the Federal Tax Service for the period from 01.10.2017 to 05.10.2021, the number of small and medium-sized enterprises, including individual entrepreneurs, had a negative trend (Fig. 1). In January 2017, there were 31,490 business entities in the Tambov region, and in 2018 there were 32,731 small businesses, an increase of 1,241 entities or 3.93 %.

In January 2019, there were 32,023 units; compared to 2018, there was a decrease of 768 units or 2.34 %. In January 2020, compared to 2019, there was again a decrease in the number of small businesses by 589 units or 1.83 %. Such a reduction in 2020 was due to the pandemic associated with the COVID-19 infection, which captured the whole world and had a significant impact on the economy, the Tambov region was not spared, many small businesses could not survive during this period, which led to the closure and decrease number of small businesses.

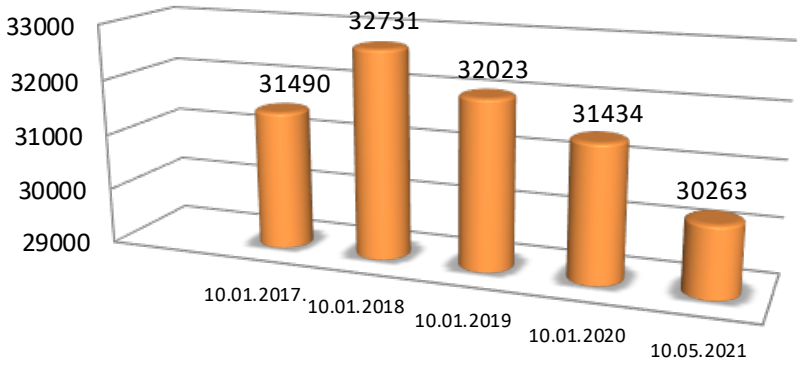

Fig. 1. Dynamics of the number of micro, small, medium-sized enterprises in the Tambov region for the period for the period 10.01.2017–10.05.2021

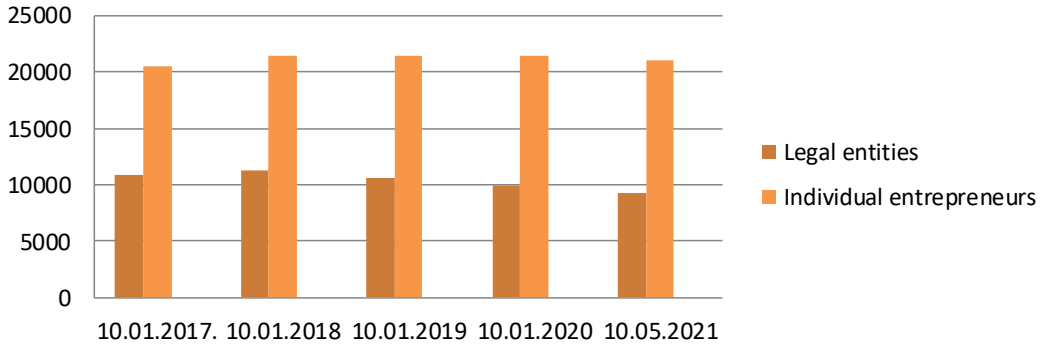

Fig. 2. The structure of small business in the context of legal entities and individual entrepreneurs in the Tambov region for the period 10.01.2017–10.05.2021

Another reason for the exclusion of SMEs from the Unified Register of Small and Medium-Sized Businesses is the failure to submit reports on time, including information on the average number of employees employed in small and medium-sized enterprises. As of May 10, 2021, there are 30,263 small businesses.

Consider the structure of small and medium-sized businesses. Statistical data show that during the period under review, legal entities (micro, small and medium-sized enterprises) accounted for 30 - 36 % of all small businesses (Fig. 2).

The number of legal entities in the Tambov region for the period from 2017 to 2021 has an annual downward trend. In 2017, the number of legal entities was 10,943 units or 35 % of the total number of legal entities and individual entrepreneurs. Over the years, the number of legal entities has decreased and in 2021 amounted to 9211 units or 30 % of the total.

Almost 65 % of all small businesses in the total volume of enterprises were individual entrepreneurs. From 2017 to 2018, the number of individual entrepreneurs increased by 945 units (4.6 %). In 2020, there was also an increase in the number of individual entrepreneurs compared to 2019 by 72 units or 0.33 %. But in 2021, compared to 2020, the number of individual entrepreneurs decreased by 459 units or by 2.13 %, this is also due to the pandemic that occurred around the world, many organizations could not cover losses and closed.

As it is known, micro-enterprises are enterprises with an average number of employees up to 15 people and not exceeding an income of 120 million rubles. Small enterprises are those

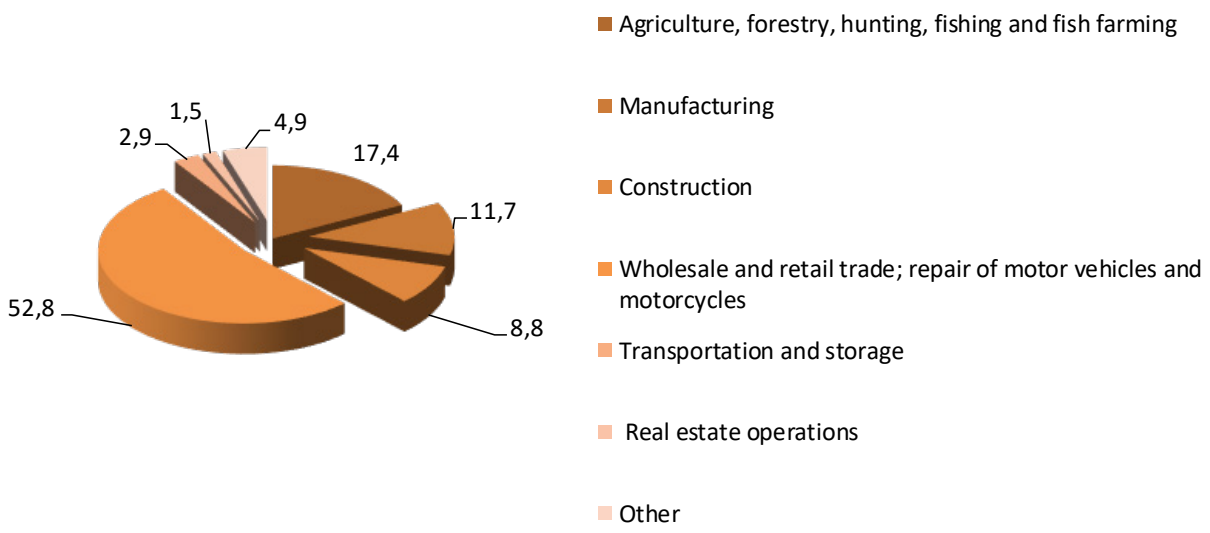

Fig. 3. Sector-wise structure of small enterprises (excluding micro-enterprises) in the Tambov region in January-December 2020

with an income of no more than 800 million rubles and an average headcount of up to 100 people. And for medium-sized enterprises, the income should not exceed 2 billion rubles and exceed the number of employees of 250 people.

Most of the Tambov region companies are micro-enterprises. Their share in the total number of small businesses ranges from 95.6 % to 96.1 % from 2017 to 2021.

The share of small businesses in the Tambov region ranges from 3.5 to 4.5 % in the period 2017–2021. The smallest part in the structure of small businesses is made up of medium-sized enterprises, their share in the total number from 2017 to 2021 slightly changes and amounts to 0.3–0.4 %.

In 2017, the average number of employees was 83,601 people, and in 2018 there was an increase of 2,544 people or 3.04 %, which indicates that the number of new jobs increased in the Tambov region due to the opening of new enterprises. But since 2019, there has been a downward trend in the number of employees in small businesses. In 2020, the average number of employees was equal to 77965, and in 2021 it decreased by 283 employees or 0.36 %. The main decrease in the number of people employed in small businesses in the region occurred in microenterprises. This decline can be explained by the fact that many enterprises left the market due to the pandemic; most enterprises had nothing to pay wages to employees.

By the type of activity, the structure of small enterprises (excluding micro-enterprises) in the Tambov region in January-December 2020, as a percentage of the total is shown in Fig. 3.

The main activity of small enterprises is retail trade, repair of vehicles and motorcycles; their share of the total number of small enterprises is 52.8 %. The activity of organizations in the field of agriculture occupies 17.4 %, manufacturing – 11.7 %. Construction enterprises and organizations account for 8.8 %, real estate transactions – 1.5 %, transportation and storage – 2.9 % of the total number of small enterprises. A slightly different structure is by type of economic activity for individual entrepreneurs. The largest number of individual entrepreneurs is employed in trade (45.3 %), transportation and storage (16.1 %), and agriculture (15.9 %).

Thus, we can conclude that it was the restrictions introduced in 2020 due to the pandemic that had a significant impact on the development and functioning of small businesses in the region. Moreover, the impact occurred on the entire chain of manufacturers and suppliers, which

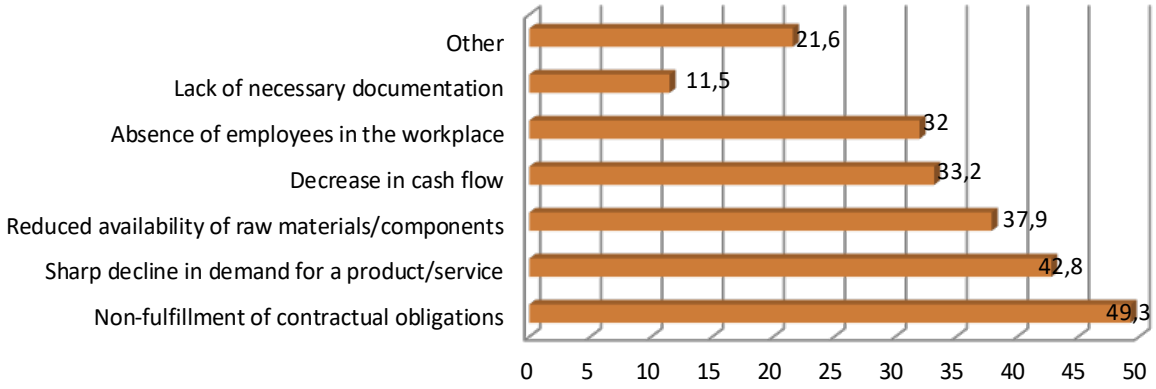

Fig. 4. Risks arising from the COVID-19 pandemic, which had a significant impact on the development of small businesses

ultimately resulted in a decrease in demand and purchasing power, thereby causing problems in business activities, which led to a reduction in the number of small businesses.

The pandemic has significantly affected the number of people employed in small and medium-sized enterprises, including individual entrepreneurs. In the region, about 12.5 thousand small and medium-sized businesses operated in the most affected sectors of the economy. The restrictions imposed in the Tambov region to prevent the spread of a new COVID-19 infection have generally affected the entire range of small business activities.

When starting a small business, entrepreneurs face a system of internal and external risks, depending on the type and scope of their activities.

External risks are caused by political, macroeconomic, natural, demographic and other factors. Internal factors are related to what happens inside the operation of the business. These include such risk factors as: a break in production, the lack of important financial knowledge from the management company, the low competitiveness of the enterprise, etc.

According to experts from the Russian Union of Industrialists and Entrepreneurs, the main risks affecting the functioning and development of SMEs during the crisis caused by the COVID-19 pandemic include: interruptions in the activities of counterparties, failure by counterparties to fulfill contractual obligations; a sharp drop in demand for a product / service; reduced availability of raw materials / components; decrease in cash flow (money does not come on time or at all due to bankruptcy / withdrawal from the counterparty market); the absence of employees in the workplace; costs that are directly related to ensuring the safety of employees during a pandemic; lack of a mechanism and tools for anti-crisis management; reduction of employees, etc. Figure 4 shows the risks, located depending on the degree of influence on the activities of small businesses.

Such changes have had a significant impact on business processes within organizations. Some employees switched to remote work, some were fired due to the impossibility of financial maintenance of the entire staff. Some organizations provided employees with an additional range of support during the pandemic: protective equipment (masks, gloves, wipes, antiseptics, and hygiene products), transportation of employees to and from work, payment for work in a certain mode.

One of the main problems of restructuring the market structure to reduce the losses from the crisis is the uncertainty about how the situation will develop. Since the crisis is only developing, it is impossible to predict the depth of the change.

However, for small and medium-sized companies in this situation there is also a positive moment, since such organizations are more flexible, quickly respond to market changes and can adapt to new realities, restructure their business model and thereby optimize their costs. Practice shows that in times of crisis there is still someone on the market who can quickly adapt their plans. However, modern realities require not only the adoption of anti-crisis measures, but also the introduction of a flexible business organization system throughout the entire life cycle of the company.

An important task of the Government of the Russian Federation is to organize risk aversion through state support for the development of small and medium-sized businesses during the COVID-19 pandemic and quarantine restrictions on economic activity.

Summing up, it can be argued that with further state support for small business; it is possible to minimize the number of enterprises that cannot withstand the debt burden and will close in the near future. However, businesses need to develop various strategies to keep the business running.

According to the research agency Synopsis Group, 57 % of small businesses say that the COVID-19 pandemic has led to an acceleration in the digitalization of firms, 38 % noted a change in corporate culture, 29 % believe that the COVID-19 crisis contributed to the elimination, reorganization of inefficient departments and processes. Thus, one can note not only the negative impact of the pandemic on the economy, but also the positive ones, because it served as a catalyst for the processes of integration and digitalization of the public and business sectors.

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Анализ состояния и проблемы развития малого предпринимательства в современных условиях (на примере Тамбовской области)

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Ключевые слова и фразы: внешние и внутренние риски; малые предприятия; предпринимательская деятельность; предпринимательские инициативы; предпринимательство; региональные программы.

Аннотация. Целью данного исследования является анализ и определение проблем развития малого предпринимательства Тамбовской области в современных условиях. Задача исследования заключается в проведении анализа современного состояния малого бизнеса Тамбовской области, а также возможных рисков в современных условиях.

Основной гипотезой исследования является предположение, что пандемия существенно повлияла на развитие малого предпринимательства в регионе, что привело к сокращению числа субъектов малого предпринимательства. Методами исследования являются научный поиск, обобщение, анализ, систематизация. Полученные результаты исследования показали, что пандемия 2019 г. привела к сокращению числа субъектов малого предпринимательства, но практика показывает, что в современных условиях кризиса необходимо быстро адаптировать свои планы. Современные реалии требуют не только принятия антикризисных мер, но и внедрения гибкой системы организации бизнеса, а также поддержки предпринимательских инициатив и региональных программ для развития малого предпринимательства.

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A Model of Organization Development with Knowledge Management and Organizational Culture Tools

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Key words and phrases: organizational development; organizational culture; knowledge management.

Abstract. The purpose of the article is to develop a model for the development of an organization with knowledge management tools and organizational culture. The research hypothesis is based on the assumption that organizational development is a multi-level process of dynamic transformation of agreed management tools: organizational goals, knowledge management goals, and organizational culture. General theoretical methods of research are the analysis of theories and concepts, modern achievements in the field of management theory in the field of knowledge management, organizational culture, and development of management systems. The research methods for forming the model were: a system approach for presenting the model as a methodological approach to the study of control systems.

For our research, organizational culture is considered from the perspective of a systematic approach, which implies its analysis through the prism of norms and rules, structural relationships, leadership styles and values.

Innovative knowledge is an initial component of innovation and a prerequisite for updating functional and key competencies, as well as an important component of organizational ability to change. Implicit knowledge accounts for 80 % of the organization's knowledge, including experience, intuition, skills, impressions, and opinions. Based on these findings, we propose a model for the development of an organization with knowledge management tools and organizational culture.

This model represents the level relationships of the organization's goals with the goals of knowledge management and formed organizational abilities, on the one hand, and the type of organizational culture and values formed by it. The development model is a hierarchical, level-based, consistent system consisting of elements of knowledge management and organizational culture. The goals of the organization at each level of development are provided by organizational abilities, which in turn are formed by the corresponding knowledge management goals of this level. The corresponding type of organizational culture at each level of the hierarchy generates values corresponding to this type of culture, which ensure the goals of the organization and are

consistent with the goals of knowledge management and organizational abilities.

We consider the ratio of elements of the proposed model. According to the theory of the organization's life cycle, at the stage of creating a company, the main goal of the company is survival, which is achieved by making a profit. The main and consistent goal of knowledge management at this level is the formation of routine knowledge, i.e. the company needs to learn how to earn a living, according to the definition of S. Whitner [1]. Routine knowledge is the knowledge that the firm uses in constantly repeating formalized processes. This knowledge is the basis for the development of relevant competencies in the company.

The goal of knowledge management to create routine knowledge at this level forms the necessary competencies of the company, which we have designated as functional, representing the ability of the organization to perform production and commercial functions in a simplified formalized way. On the part of the organizational culture block that provides the company's goal at this level and is consistent with the goal of knowledge management and organizational ability, there will be the following types of culture: survival and belonging, in the interpretation of the theory of spiral dynamics by K. Graves and his followers [2], according to which the presence of certain programs at each level of development.

Cultures of survival and belonging involve the staff's attitudes to the external environment as an unpredictable and insecure world. It creates groups based on the family type. Traditions and habits form clichés for behavior and occur in small companies at the formative stage. The founding entrepreneur is perceived as a spiritual leader, a guardian, and a source of hope for survival. The basic values formed under the influence of this type of culture are instincts and safety.

Having a certain base for survival, the company moves to the next level of development, the goal of which is growth. This goal corresponds to the stage of the life cycle-economic growth, which characterizes the increase in production volumes, sales markets, i.e. an increase in performance indicators, which can occur in an extensive or intensive way. To achieve the goal of economic growth, it is necessary to set a goal from the knowledge management unit – the creation of organizational intelligence, the implementation of which will require the formation of key competencies. G. Hamel and K. Prahalad [3] defined them as the most important abilities that determine the company's strategy and performance.

Creating organizational intelligence requires more complex management actions. Organizational intelligence is understood by us as the ability of an intellectual organization as an organized, complex, dynamic system to produce organizational knowledge, self-learn and form key competencies for continuous development. As a result of the action of a system of interrelated elements of collective intelligence, enhanced by information and communication technologies, a new qualitative education is obtained-organizational intelligence, which is due to the property of the emergence of the organization as a system [4].

At this level, the values that ensure economic growth and the corresponding knowledge management goals for creating organizational intelligence are power, order, and success, which in turn will be formed under the influence of such types of culture as: power, rules, and results. A culture of power presupposes authoritarian leadership, domineering principles that play an important role, and the leader is a dictator who stands above the rules of the organization. However, economic growth can also be achieved on the basis of rules and laws, which implies a different level of managerial influence, less authoritarian, based on a larger bureaucracy that requires more standardization. The culture of success presupposes attitudes to achieve results at any cost, pragmatic, creative problem solving. Finally, moving to the next level, the organization has a new goal-development/economic development. We understand development

as a process of irreversible purposeful transformation, updating of production processes, which makes it possible to move to a qualitatively new level of activity [5].

The bases of qualitative changes are technological and organizational innovations. A prerequisite for achieving the goal at this level is that the organization has dynamic abilities. According to D.J. Thies, dynamic abilities exist if the organization can identify new opportunities [6]. At the same time, the company does not just respond to changes in the external environment, but develops the necessary abilities ahead of time, is able to work with knowledge as assets, choose the optimal organizational forms, and allocate resources. For the formation of dynamic abilities, it is necessary to set the goal of knowledge management, which consists in the formation of organizational consciousness.

Organizational consciousness sets the vector of development of organizational intelligence, forms the system and strategic thinking of personnel, as well as the dynamic abilities of the organization, which is a necessary condition for its economic development. Organizational consciousness is the highest form of reflection of an objective real organization in the consciousness of personnel, which forms the systematic and strategic thinking of personnel, ensuring the creation of dynamic abilities of the organization as a necessary condition for its economic development.

The values that correspond to this level are people, development, and balance, which are formed by the corresponding types of culture: harmony, development, and balance. The essence of a culture of harmony is community of interests, harmonious relations, cooperation, and creativity. Work is an opportunity to improve the world and develop the environment. The culture of development is orientated to the principles of evolutionary progressive, harmonious development. Work is the pleasure and happiness of self-expression. As a result of theoretical research, analysis and synthesis, a model of the organization's development through knowledge management and organizational culture has been developed, which includes agreed forming and providing elements such as: organization goals, knowledge management goals, organizational abilities, values, organizational culture at the levels of organization transformation: survival, growth and development.

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Модель развития организации инструментами управления знаниями и организационной культуры

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Ключевые слова и фразы: организационная культура; организационное развитие; управление знаниями.

Аннотация. Целью статьи является разработка модели развития организации инструментами управления знаниями и организационной культуры. Гипотеза исследования: развитие организации – уровневый процесс динамической трансформации согласованных инструментов управления: целей организации, целей управления знаниями и организационной культуры. Общетеоретическими методами исследования явились анализ теорий и концепций, современных достижений в области теории управления в области управления знаниями, организационной культуры, развития систем управления. Методом исследования для формирования модели послужил системный подход для представления модели как методологический подход к исследованию систем управления.

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Evolution of the Management Accounting System at Various Stages of the Introduction of Innovations in Mechanical Engineering

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Key words and phrases: mechanical engineering; management accounting; innovation; innovative project; information and analytical support.

Abstract. The relevance of the research topic is due to the fact that in the conditions of an innovation-oriented market economy, the need for a timely response on the part of machine-building enterprises to the instability of the external environment, as well as to changing consumer preferences in the innovation sphere. The purpose of the presented article is to analyze the evolutionary development of management accounting as one of the crucial factors of the innovation process at machine-building enterprises. The general concept of the work implies the disclosure of theoretical and practical aspects of the organization of management accounting of innovations at machine-building enterprises based on the analysis of evolutionary development. Management accounting is considered in the study as a tool to promptly meet the growing information needs of the organization's managers in the innovation process within Industry 4.0. The work is an attempt to comprehend the tendencies of changing the paradigm of management accounting in the innovation process of machine-building enterprises and can become the foundation for further conceptual and applied research of the modern phenomenon of innovations in machine-building and its information support.

Introduction

The concentration of companies on the accumulation and development of innovative

components, and further emphasis on them during the competitive struggle of manufacturers led to the emergence of such a type of competition as “innovative competition”. Being the basis for the development of price and non-price competitive advantages of manufacturers, innovations become the basic reason for the formation of the “innovation paradigm” that has been formed today competitive relations, as well as a set of new approaches to the regulation of innovations. Taking into account the fact that the fundamental factor of successful project activity has become the efficiency of innovation, it is possible to note the effect of the spread of competition not only to the markets of goods, but also to the labor and capital markets. The effect of accumulation of economic potential and intensification of production processes by the introduction of innovations in its base has specific, multidimensional and diverse advantages, the application of which includes both economic activity and work in various markets. We are faced with a situation when the formation of a new qualitative superiority in the field of manufacturer’s competencies occurs solely due to the volume of innovations and is accompanied by an expansion of the possibility of influencing the parameters of the functioning of the market, its structure and conjuncture.

The globalization of the economy, increased competition lead to a shrinking product life cycle and force enterprises to innovate. In modern conditions, the development of a machine-building enterprise and ensuring its high competitiveness, in most cases, is possible only through the development of innovations. The transformation of production factors occurs along the path of their intellectual and informational shaping. In this regard, new requirements arise for the organization, forms and methods of enterprise management (Rogulenko et al., 2020). The specifics of the management activities of innovators can include: the complex and ambiguous nature of innovations, significant risks at the stages of innovation implementation, etc. The successful existence of an enterprise in conditions of market competition is predetermined by the correct selection of tools for innovative development. A key role in this process is played by the formation of an information base for innovation, which underlies the process of formulating strategic attitudes and making tactical decisions to achieve the development goals of an organization (Bodiako et al., 2016; Rogulenko and Smolyakov, 2017). The solution to the problem of filling the information vacuum that exists in the innovative segment of an economic entity’s activity can be achieved by organizing a specific management accounting and analysis module that accumulates data related to this direction of enterprise development.

The most promising areas in the development of management accounting can be attributed to innovation accounting, in particular its sections aimed at providing the company’s management with information that allows improving the efficiency of innovation management. The information accumulated in the innovation management accounting system can be used as a basis for the analysis of the innovation environment and the innovative potential of the enterprise, and as a basis for planning and implementing innovations, as well as monitoring the degree of implementation of the goals of innovation and the effectiveness of this process (Lu et al., 2020). For this reason, management accounting is an objective necessity. The list of management accounting functions at the present stage has significantly expanded and is not limited to issues of managing production and circulation costs, monitoring the timeliness and quality of execution of decisions made, and cost regulation. Competitive conditions make it the responsibility of innovation managers to analyze the micro- and macroeconomic environment, study technical, organizational, marketing innovations existing in the market. Based on this, their information needs are formed, which determine the need for the formation, development of management accounting, which ensures effective management of the enterprise’s innovative activities (Souza and Gasparetto, 2020).

The purpose of the study is to analyze the evolutionary development of management accounting as one of the crucial factors of the innovation process at machine-building enterprises.

Materials and Methods

In the course of the research, a systemic and process approach to the problems under study, general scientific methods were used: analysis and synthesis, induction and deduction, modeling, as well as methods of systematizing the studied theoretical and practical material. Management accounting is considered in relation to competitive advantages of machine engineering enterprises, achieved due to competent organization of innovation management process.

As a methodological basis, it should note the study of the cyclical concept of the innovation process as a methodological basis for management accounting and analysis of innovations, as well as disclosing the essence of the decision-making process from the point of view of the information needs of the management personnel of the enterprise; systematization of methodological support of management accounting and analysis of innovation processes, proposal and justification of a possible version of the applied methodology for organizing the collection, systematization and interpretation of information necessary for making management decisions in the innovative segment of the enterprise. Also, for the study, some concepts of the modern theory of competition have been applied – in particular, coopetition concept. Management accounting and innovation are considered in the context of the Industry 4.0 concept and its features in mechanical engineering. Taking into account the peculiarities of the current stage of economic and social development that form a globalized attitude to competition, it is possible to note the transformation of the concept of “competition” under the influence of factors of globalization and the “new” technological revolution associated with the emergence of new, nano-, bio-, cognitive and information and communication technologies.

A high degree of coordination of activities, integration and cooperation of key market participants are becoming generally accepted forms of competitive behavior. The existence of a growing need to study new characteristics and properties of competition arising as part of the transition of society to a post-industrial way of life, which will make it possible to align information support of the innovation process in accordance with the ecosystem of innovations as a critical factor in the success of engineering companies in local and global markets. Analysis of the information and analytical support used by the management of machine-building enterprises shows that the state of the management accounting system often does not meet current needs, in particular, there is no possibility of taking into account numerous changes occurring in the external environment and generating information that allows managers to effectively manage innovations (Chiesa et al., 2009). Accordingly, there is a need to develop specific recommendations for management to improve and develop the management accounting system, taking into account the various stages of the implementation of an innovative project.

Results

Solution of the issue of increasing the efficiency of machine-building production while ensuring the competitiveness of manufactured products looks difficult to implement in the case of a low degree of intensity of innovation. The situation that most companies are currently dealing with has a characteristic feature in the form of the need to form an effective innovation management subsystem, the role of which is to ensure growth competitiveness of a machine-building enterprise in the long term. At the same time, the effectiveness of this innovation management subsystem largely depends on its information and analytical support, which is achieved with the help of management accounting. Simultaneously, at machine-building

enterprises, management accounting for innovations forms the corresponding accounting and analytical information at each stage of innovation management. For the initial stage, the limited functionality of management accounting of innovations is characteristic, implying the collection of information about the innovation environment and the innovative potential of the considered machine-building enterprise.

Such information can be used in their own developments, subject to the assumption of the correctness of the implemented market research of competitors, allowing them to turn existing resources to already existing (implemented) innovations used in products and, possibly, consider the possibility of their modification. In addition, at the first stage, information can be generated about the possibilities of improving new and introducing promising technological processes, within the framework of the implementation of innovative projects, the degree of readiness of equipment for the production of innovative products can be assessed, and relevant data on the availability of the required resources (financial, labor, material) necessary in the process of implementing an innovative project can be obtained.

The second stage is characterized by the formation of a complex of management information necessary in the process of clarifying the goals of innovation implementation, within the framework of this project, and the comparability of the project objectives with financial and non-financial capabilities, taking into account the formation of a preliminary plan for solving the tasks. A feature of this stage is the consideration of the role of management accounting of innovations, in the context of the company's innovative goals expressed in specific financial and non-financial financial indicators used to assess the degree of achievement of these goals. At the same time, it seems expedient to the authors to periodically review and change the developed indicators, the system of accounting for the effectiveness of innovation management, the analytical functions of which allow to determine with greater accuracy the moment when changes are needed (Chenhall, 2003; Bodiako and Ponomareva, 2018).

The third stage is characterized by obtaining information from the management accounting of innovations, through which the current control of the effectiveness of innovation implementation can be implemented, as well as local adjustment of the innovative goals and objectives of the enterprise, taking into account changing internal and external conditions. The final stage of management accounting of innovations implies the formation of management reports containing information that allows to assess and monitor the degree of achievement of the established innovative indicators of the enterprise, as well as motivation of employees, in the context of the results achieved. Therefore, efficiency in the field of innovation management is a function of the quality of managerial information generated in the management accounting system and the efficiency of its processing in the process of implementing an innovation project. Taking into account the wide range of tools (methods of analysis and accounting) used by management accounting, it is possible to distinguish the main ones, in particular: strategic budgeting, strategic analysis, cost accounting by type of activity, economic value added model, balanced scorecard, etc.

Recently, there has been a trend according to which a significant number of machine-building enterprises in the post-Soviet space and in Russia are implementing a balanced scorecard as one of the main management accounting tools, which allows using various financial and non-financial performance indicators to assess the degree of achievement of the innovation project targets (Busco and Quattrone, 2015). For example, this approach is used at JSC "EMZ named after V.M. Myasishchev", JSC "NITS named after V.F. Solinov", and Central Institute of Aviation Motors (ex FSUE "TsIAM named after P.I. Baranov"). A set of reporting information is generated separately for each of the forecast reports of the balanced scorecard system innovation and is

provided to the project management with the required frequency (depending on the scale of the innovation project) (Gorlov and Rogulenko, 2016; Souza and Gasparetto, 2020).

Due to the fact that innovation processes considered in the context of management accounting are a chain of operations or events, each stage of which corresponds to a change in the additional value of a product or service, it is necessary to take into account the sequence of processes and value addition at each of these stages, as well as the existence of such a term as “value chain”. (Busco and Quattrone, 2015). Timely information support of the management system, grouping of analytical data into sections that allow for the identification of patterns of development of management objects, is one of the main requirements for the accounting function (Orlov, 2017).

It should be noted that the objectives of the innovation project are: offering a certain degree of novelty of the innovative product and reducing the time costs associated with its development, identifying new markets and new consumers (Orlov, 2018; Machado et al., 2021). The tasks of optimizing the innovative activity of a machine-building enterprise by the criterion of the maximum efficiency of its production activity are brought to the fore.

In this regard, the issues of formalization of innovation, the development of algorithms and methods for achieving particular objectives of innovation, and the use of information technology in the innovation of an enterprise are of paramount importance (Lu et al., 2020). To date, a classification model of innovations has been developed, which includes new features – the priority of implementing innovations and their impact on the rate of innovative development (Dubrovina and Gorelova, 2020). This makes it possible to rank innovations according to their importance for the enterprise and to streamline the process of planning innovative development, to analyze their impact on the degree of innovative development of the enterprise, to more fully assess their effectiveness, and, ultimately, makes it possible to build an adequate management system for the innovative development of the enterprise. Significant costs incurred by a machine-building enterprise when introducing technological or productive innovations are fraught with colossal losses arising in the event of negative development of external and internal processes in the company.

Comparison of the markets of high-tech products and consumer goods shows such features of the market of high-tech products: an increased level of risk associated with the development and launch of the product to the market (venture investments); high dynamism of market processes in the industry; increased competition; increased importance of the manufacturer’s image; “weakness of the buyer’s market forces”; insignificant importance of the price factor for the consumer when buying a high-tech product (Jamil et al., 2016; Orlov, 2019). The correlation of the features of innovative competition is mainly associated with the clear dominance of certain groups of goods (gadgets, automotive industry, etc.).

Discussion

The conceptual and practical concept of innovative efficiency is closely related to the issue of organizing the management accounting system during the implementation of innovations and its stages. However, it is obvious that if the value of material resources is adequately determined by traditional methods and for management accounting of innovations, then the corresponding assessment of intangible and human resources, taking into account the factor of intellectual capital for the same purposes, is a significant problem. It should be emphasized that the innovative activity of machine-building enterprises has its characteristic features:

1. Innovations in mechanical engineering very rarely bring so-called “quick money”.

Moreover, any delay in introducing new technology threatens to irrevocable loss of investment in the event that one of the competitors turns out to be more agile in mastering similar products and has time to capture the market (Kerzner, 2014). Therefore, it is very difficult for manufacturers of machine-building products to attract external investors, so, in most cases they have to finance innovations from their internal reserves.

2. The costs associated with the modernization of industrial equipment in order to improve its environmental friendliness are actually irrecoverable in the short and possibly even in the medium term (the return of such costs is mainly associated with the growth of goodwill). At the same time, modern increased requirements for the ecology of industrial facilities force to invest funds in the process of improving environmental friendliness (Englund and Gerdin, 2014; Busco and Quattrone, 2015).

Accordingly, from the above, this determines the exceptional importance of management accounting as a source of information for the innovation process. The process of forming a management accounting system when implementing an innovative project differs from the process of forming a management accounting system when implementing a project to create a product with a low degree of novelty (a product that cannot be classified as innovative). The activities of technology leaders are characterized by the presence of highly qualified scientific personnel, the use of the most modern tools for research and development (R&D), the generation and implementation of new knowledge of high relevance, high research and development costs and, as a result, the introduction of new high-tech competitive products to the market. Followers of technology leaders also leverage new knowledge and drive research and development, but their products tend to be modifying innovations that improve on existing products. It is clear that leaders face disproportionately large risks and the information that supports the innovation process must be as accurate as possible. Thus, the quality of management accounting in this case is of critical importance. Mechanical engineering can be defined as “the production of capital goods” (Machado et al., 2021). With such a broad definition, this industry includes dozens of areas: from transport and power engineering to machine tools and instrument making. In the new century, the industry is changing, and the pace of change will only accelerate.

The mechanical engineering industry expects more changes in the next five years than the industry has experienced in the last 20 years, McKinsey&Company (McKinsey&Company, 2021) analysts write. In the automotive industry alone, the share of traditional technologies and business models, as opposed to innovative ones, will decrease from 98 % of the market to 50 % in the period from 2017 to 2030. The annually created value of products in this segment will double over the same period from $3.5 trillion to $6.6 trillion. The increasing complexity of the product, the integration of digital innovations and the Internet of things into it lead to an increase in the cost of its creation. Accordingly, the budget for R&D is also increasing (now the industry leaders have it at 2–5 % of revenue). At the same time, the development and introduction of a product to the market should take as little time as possible, so both the speed and quality of innovation are the key ones to competitiveness. The said McKinsey&Company survey showed that the leaders of machine-building firms are aware of the effect of introducing innovations, but are not yet ready to put them into practice. The pace of innovation will help accelerate a two-speed approach to R&D – the parallel implementation of related processes. In the automotive industry, it will be able to shorten the development cycle from 50–60 to 6–24 months (Souza and Gasparetto, 2020). The quality of the product and its technological level are becoming increasingly more important for the client, so companies must both develop a good product using all modern tools (Big Data, Internet of things) and provide after-sales service.

All these tools of the future – Big Data analysis, machine learning, the Internet of things,

3D (3-dimensional) printing, virtual reality, drones, robots and more – belong to the so-called Industry 4.0, the perception of which is the key to increasing competitiveness and internal efficiency. In the context of considering Industry 4.0, there are opportunities to increase productivity due to a number of technologies that are used not only in the production cycle, but also throughout the value chain. Timely implementation of Industry 4.0 tools can become a factor that will make it much easier for Russian companies in the machine-building industry to achieve competitiveness in terms of cost and quality compared to international players, in the face of sanctions. Optimization production processes up to the level of efficiency of world industry leaders can become a factor that frees up additional resources for research. Trends in recent years indicate a shift in growth points and profitability towards the service business, software and value-added services. Manufacturers are moving beyond traditional businesses to develop digital technologies, advanced analytics and value-added services. All this lowers the total cost of ownership for the consumer. New sources of income will occupy increasingly more place in the sales structure. For example, an enterprise will need to develop digital competencies or enter into close partnerships with IT (information technology) companies to create added value. The MyJohnDeere (MyJohnDeere, 2021) platform is a good example of this. As another factor, for example, intersectoral cooperation and so on can be considered.

Most innovations with increased margins will be born precisely at the intersection of industries, and it is desirable for companies to develop their strengths by outsourcing non-core competencies. A good example of such a collaborative ecosystem is the HERE 3D road scanning project for self-driving cars. Various functions in the project were performed by giants like BMW (Bayerische Motoren Werke), Intel, Nvidia, Pioneer, and others. In general, as the market becomes more complex, the concepts of competitors, partners, and customers will be rethought. The growth of the ecosystem is clearly visible in the example of the automotive or aviation and spacecraft industry, where the interests of IT corporations and high-tech competitors like Tesla are already included in the traditional manufacturer-supplier scheme. Management accounting in such conditions should become evidently more intelligent and based on Big Data and advanced analytics. In many cases, the management of companies does not have sufficient information about the impact of innovation policy on the financial result of their activities, not only in the long term, but also in the current period due to insufficient accounting and analytical support for innovation. The most important reasons that make it difficult to account for the cost of innovation can be summarized as follows:

– the uncertainty of the final results of most scientific research. The result of a scientific project is more uncertain than the result of production activities;

– there is a significant period of time between the beginning of the implementation of a scientific project and the determination of the final result;

– the complexity of evaluating scientific research, which in a significant number of cases is intangible in form (Dash et al., 2018).

In addition, one of the areas contributing to the commercialization of technologies and the improvement of accounting for innovations is benchmarking. The benchmarking method was developed by the Institute for Strategic Planning (Cambridge) and is formulated as follows: in order to determine an effective solution in the field of competition, it is necessary to consider the experience of other companies that have achieved success operating in similar conditions. Xerox made a significant contribution to the development of its practical component; namely in this company the term “benchmarking” appeared in 1979 (Busco and Quattrone, 2015). Practice shows that the most successful innovations are often distributed by copying (including illegal), reengineering. There are cases when copied innovations are supplemented with their own

developments and, as a result, a synergistic effect arises. The legal use of the achievements of other companies in the framework of Benchmarking allows you to use the developments of competitors, however, for such an approach, additional costs are likely to arise, so most often the competitive approach is used as a tool to reduce production costs. Just as the tendency to constantly find ways to reduce development costs is characteristic of IT companies, a similar situation is observed in the market of innovations in mechanical engineering when developing innovative products. One of the ways, in this case, is benchmarking. As a process, benchmarking is, firstly, comparing the results of an organization's activities with the effectiveness of other organizations (competitors, leaders, etc.), secondly, searching, studying, analyzing the best business practices and, thirdly, adapting the successful experience of others in their own organization.

Accordingly, at various stages of the introduction of innovations in mechanical engineering, the tasks of management accounting are modified and complicated. It should also be noted that various innovations carried out at machine-building enterprises may differ significantly from each other in terms of functionality, technology, design, and element content. In particular, one of the most important tasks of assessing the innovative potential of an enterprise is to identify the so-called innovative barriers that arise in the process of managing innovative potential as part of the implementation of an innovative project. Machine-building products manufactured using high technologies may not belong to the category of high-tech products, however, the inclusion of advanced technologies and the latest construction materials in the technological process contributes to the transition to a higher technological level of production and creates the preconditions for expanding the range, increasing the consumer properties of products and growth of manufacturer's influence on the industry market. In addition, experts note the growing interest of private sector companies in new forms of cooperation based on the type of cooperation due to the complication and rise in the cost of research and development, a decrease in the duration of production cycles for high-tech goods, the need for the integrated use of various technologies to solve commercial problems of a global nature (Gorelova and Ryazheva, 2017).

Various forms of interaction between the state and private business have also acquired particular importance: joint public-private institutes and laboratories, cooperation of scientists, development of joint programs and projects, exchange of information flows, etc. (Englund and Gerdin, 2014). Engineering companies need to start by setting ambitious goals and developing an innovation strategy. It is necessary to outline target sales markets and target business model. Market conditions are changing and the implementation of the strategy will require operational changes and changes in the management accounting system. It must become convergent and synergistic. The widest possible search for opportunities for innovation, including outside the industry, is required. A streamlined development and innovation process is essential to keep the company's operations as fast and flexible as possible. Decision making tools and mechanisms need to be provided to make the process flexible and efficient. Perhaps the most important factor is the culture of innovation. On the one hand, this is an understanding of the customer's needs, which should be translated into the "terms of reference" for engineers. On the other hand, it is a general corporate culture, teaching employees to take risks and experiment.

Conclusion

According to the results of the study, the role of management accounting in the information and analytical support of management has been established. The study examines the context

of the formation of managerial information about the external and internal environment of the company, taking into account the specifics of budgeting, within the framework of the implementation of an innovative project in specific indicators. The authors considered the factors of increasing the efficiency of resource use, in particular, evaluated various methods of monitoring budget execution based on information about the achieved planned value of indicators and the reasons for deviation from them; the context of informing the participants of the innovation project about its current status is considered, in order to optimize the information support of management; the issue of forming information about the costs of the enterprise in accordance with the list of typical analytical characteristics is considered. It is established that the management accounting systems used in a number of projects do not meet the requirements of information support for decision-making by the management of the innovation project.

From the above, the following conclusions can be drawn:

– achieving real results of innovative engineering projects in modern conditions is possible with minimal deadlines for the implementation of innovative projects and strict implementation of the project implementation schedule;

– even a short-term interruption of innovation activity can lead to a rapid loss of a significant number of customers, in particular, this effect is due to the accelerated development of a modern component base of components and a wide range of various materials, along with the unprecedented growth of information technology, which provides more “mobile” and flexible competitors with competitive advantages;

– a feature of mechanical engineering is the attraction of problematic attraction of external investors, in particular, there is a need for a rather laborious pre-investment study of the project with the preparation of feasibility studies that clearly indicate the attractiveness of the project (payback period and further income, marginality, read discounted income, etc.), but even if there are confirmed advantages, serious interest of the investor in this project is not a guarantee;

– the existing conditions force manufacturers in the machine-building industry to take on additional risks of innovation and investment in order to retain their occupied market niche.

Within the framework of clarifying the principles of innovation management accounting, the following are highlighted by authors: the economic results of innovations evaluated on the basis of the effectiveness of internal processes related to innovation, as well as the activities of personnel involved in the innovation process; the process of formation in the management accounting system innovation costs for the production of innovative products by their places of origin and centers of responsibility; a system for providing and forming a subspecies of managerial information about innovations through its analytical interpretation; the presence of a group the main information needs of managers at various stages of the evolution of an innovation project, as well as the expansion of the range of indicators used in innovation management in accordance with the evolutionary principle.

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Эволюция системы управленческого учета на различных стадиях внедрения инноваций в машиностроении

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Ключевые слова и фразы: инновации; инновационный проект; информационно-аналитическая поддержка; машиностроение; управленческий учет.

Аннотация. Актуальность темы исследования обусловлена тем, что в условиях инновационно ориентированной рыночной экономики возникает необходимость своевременного реагирования машиностроительных предприятий на нестабильность внешней среды, а также на изменяющиеся потребительские предпочтения в инновационной сфере. Цель представленной статьи – проанализировать эволюционное развитие управленческого учета как одного из решающих факторов инновационного процесса на машиностроительных предприятиях. Общая концепция работы предполагает раскрытие теоретических и практических аспектов организации управленческого учета инноваций на машиностроительных предприятиях на основе анализа эволюционного развития. Управленческий учет рассматривается в исследовании как инструмент оперативного удовлетворения растущих информационных потребностей руководителей организации в инновационном процессе в рамках Индустрии 4.0. Работа представляет собой попытку осмысления тенденций смены парадигмы управленческого учета в инновационном процессе машиностроительных предприятий и может стать основой для дальнейших концептуальных и прикладных исследований современного феномена инноваций в машиностроении и его информационного обеспечения.

UDK 69

Experimental Studies of the Effectiveness of Technological Processes to Improve the Quality of Construction Products

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Key words and phrases: technology; lightweight concrete; cellular structure; foam glass; heat insulation.

Abstract. The paper considers the general regularities of the ways of creating porous structures of materials (foaming, aggregate monolithing). An experimental research of the influence of technological processes on the properties of increasing the quality of a building mate-rial (foam concrete) is presented. The way of formation of cellular structure of light-weight concrete has been proposed and the field of application of foam-glass concrete products and structures has been defined.

Inorganic materials with cellular structure (concrete, glass, ceramics) have the prominence in modern construction. In addition to good heat-shielding properties, these materials have high rigidity, form resistance, bio and fire resistance, closed cellular structure, and so on [1; 2].

The physical and technical properties of products with a cellular structure depend on the total porosity volume and its characteristics. It is known that the main trend of improving building materials is a decrease in the of product and structure density, i.e. in-crease in total porosity. However, for inorganic materials with a cellular structure, the problem of increasing porosity is a complex scientific and technical problem, since there is a cellular structure violation and a sharp deterioration in the properties of such materials for high porosity values with traditional methods of porosity [3–5].

Energy, resource saving and environmental habitat improvement are the main technical progress directions in the construction field, including the introduction of the science and technology achievements, the development and production of new building materials obtained by technologies that conserve natural resources. The economic conditions in the country predetermine a new approach to choosing efficient building materials for housing construction. The sharp price increase for fuel, mineral and organic raw materials, the high transport cost are reflected primarily in the building material for wall products and structures.

The introduction of regional energy-saving building codes in the country makes many traditional wall materials technically and economically unacceptable [3].

Under the current circumstances, materials of mineral origin (light and cellular concrete) become the most promising thermal insulation materials. Cellular concretes maintain the position of a very effective and one of the economical wall materials [3–6].

The author has developed and proposed the composition of cellular concrete – foam glass

Table 1. Physical and mechanical properties of materials and mixtures for making foam glass concrete

Composition	Filler fraction, [mm]	Density, [kg/m³]				Strength, [MPa]	
		freshly prepared foam concrete mixture	freshly prepared FGC mixture	FGC after heat and moisture treatment	FGC in dry condition	after heat and moisture treatment in 3 days	after heat and moisture treatment in 28 days
1	10-20	800	695	600	532	1.20	1.69
2	10-40	810	640	530	465	1.22	1.58
3	10-40	830	710	655	580	1.15	1.55
4	10-20	840	675	620	500	1.53	1.94
5	10-20	940	795	630	520	1.75	2.21
6	20-40	940	765	743	670	1.10	1.45

concrete (**FGC**) with a density of 450–550 kg/m^3 was developed and proposed, based on a porous body model with cellular structure (foam concrete) and high density spherical filler (foam glass) [6; 7]. The tests have shown that the introduction of porous aggregate (granulated foam glass) into the foam concrete mixture allows to improve the physical mechanical (Table 1) and heat-insulating properties of concrete.

A significant effect of input granules on the FGC density is revealed, which became 7–20 % lighter than the original foam concrete, and the higher the foam concrete density was, the greater was the relative decrease in the FGC density. When using the fraction of 20–40 mm, the density decreased by 16–25 %, and the fraction of 10–20 mm – by 7–15 %. Comparison of foam concrete and FGC showed a significant (by 1/3) decrease in thermal conductivity: 0.19 W/(m ºC) at foam concrete density of 600 kg/m^3 and 0.10–0.12 W/(m ºC) at FGC density 450–550 kg/m^3 [6; 7].

The author proposed a physical model of a porous material consisting of the following components: portland cement, fly ash, soda glass, blowing agent, granulated foam glass.

The practical implementation basis of the proposed model of the cellular concrete porous structure is based on the set principles of processes for combining a binder with a fill, redistributing a binder in the volume of intergranular voids in the aggregate, molding and curing the product. To obtain a cellular structure of lightweight concrete of low density, it is effective to use, firstly, the principle of foamy porosity, based on the method of separate preparation of the raw mix and, secondly, the use of highly porous aggregate.

This method involves the continuous voidness filling between the granules of the foam glass with a binder (foam mixture) of the binder phase (Fig. 1). Monolithic granulation of foam glass by foam concrete mixture allows obtaining highly efficient thermal insulation and structural insulation materials and products. An important factor deter-mining the material efficiency is: high framework-forming material porosity (foam con-crete) and aggregate (foam glass), which have mostly closed pores of the correct (spherical) shape. Thus, the physical mechanical properties of the materials in question depend on the following parameters: the volumetric component content, the strength and elastic properties of the components, and the adhesive binder strength with the aggregate.

The principle of FGC composition selecting does not differ from the composition selection of

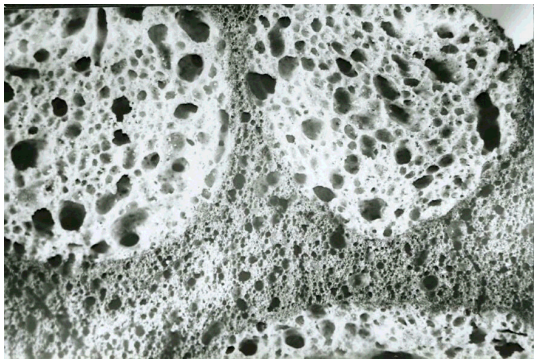

Fig. 1. The FGC sample porosity

other concretes on porous aggregates, but due to the large density difference of the aggregate and mortar part, the flaking danger must be taken into account.

The the cellular material formation sequence consists in the sequential production of semi-finished products: cement paste → foam concrete mixture → FGC mixture → FGC (Fig. 1).

One of the effective aggregates in lightweight concrete is the fly ash of thermal pow-er plants, which can partially or completely replace the fine aggregate of other species (quartz and expanded clay sand, granulated blast furnace slag, etc.), improve thermal and physical properties and significantly reduce the energy intensity designs.

It should be noted that the ash in light concrete serves two functions. Firstly, being a dispersed material, whose particle size is close to cement, ash together with cement forms a mixed ash-cement binders. Secondly, the ash grains play the role of fine aggregate, or rather the smallest fractions of this aggregate. The use of more coarse ash fractions is not recommended due to the fact that they contain a significant number of large inclusions that adversely affect the strength and durability of lightweight concrete.

For that reason, as the lightweight concrete fine aggregate, it is advisable to use the lightest ashes with a bulk density of 600–800 kg/m^3. Such ashes are characterized by a high content of porous particles and a low content of inclusions.

It has been practically established that the introduction of powdered ash into the concrete improves the technological mixture properties (workability, non-separability), increases the structure strength and uniformity, simplifies the design and significantly reduces cement consumption.

The powdered ash properties, used as a fine aggregate, have a significant impact on the lightweight concrete properties formation. The most important of them are: ash dispersion, phase, chemical and mineralogical composition, the content of unburned particles.

The porous material system formation, firstly, is achieved by separate preparation of the cement-ash solution and technical foam with the required properties. Secondly, the further mixing of the cement-salt solution with technical foam to obtain a homogenous foam concrete mixture. Thirdly, the granulated foam glass use as a highly porous aggregate for cellular and lightweight concrete requires strict adherence to technological operations. It is possible to use two methods of molding the product:

1) separate molding, which consists in pre-packing coarse aggregate into the form (in our case, foam glass granules), followed by filling the intergranular space with a solution (foam concrete mixture);

2) supply of foam glass granules to a forced action foam mixer with a horizontal shaft with

specially selected blades to reduce the fragmentation of the aggregate and uniform distribution over the volume. These production methods can be implemented with minimal capital expenditures at existing enterprises and plants produced cellular concrete. Cutting technology makes good use for the foam glass product manufacture, blocks, etc.

Conclusions

1. There are sufficient prerequisites for wide use of granulated cellular glass in the creation of construction products such as small and bulk blocks, panels, partitions and other types of building parts.

2. Production of foam glass products and structures is energy-efficient and relatively uncomplicated technology. The use of cheaper components of local production and waste – granulated foam glass obtained from waste container and building glass, TPP fly ash – significantly affects the cost of products and the environmental situation in the city.

3. The foamglass concrete obtained by monolithing granules of foam glass with non-autoclave foam concrete was 7–20 % lighter than the original foam concrete, while the thermal conductivity decreased from 0.19 to 0.10–0.12 W/m ºC.

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Экспериментальные исследования эффективности технологических процессов повышения качества строительных изделий

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Ключевые слова и фразы: легкий бетон; пеностекло; теплоизоляция; технология; ячеистая структура.

Аннотация. Рассмотрены общие закономерности способов создания пористых структур материалов (вспенивание, монолитное заполнение). Представлено экспериментальное исследование влияния технологических процессов на свойства повышения качества строительного материала (пенобетона). Предложен способ формирования ячеистой структуры легкого бетона и определена область применения изделий и конструкций из пенобетона.

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