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THE INTELLECTUAL FRAME OF THE ECONOMY

Summary. The article describes the influence of intellectual business services and IT on the innovation development and formation of the knowledge economy, features of the investments in ICT effectiveness evaluation and current problems of their effective use in management and inter-organizational interaction of the entities. It is shown that the need for the National programme for intellectual business services segment is becoming topical.

Keywords: modernization, intellectualization of the economy, consulting, institutional environment, growth points.

Overcoming the entropy of markets

A World Bank research states that economic development is an accumulation process of rather knowledge than capital (World Development Report, 1998). World economy becomes more complicated, markets become more dynamic. Their entropy increases. Production modernization, and that of branches in general, takes place more often, in fact, it becomes continuous, and its rates grow as well. The purpose of this modernization, if taken in a broad sense, is a transformation of a traditional society to a modernized one, and from the economic point of view – to production and marketing of the competitive products and services.

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Effective modernization includes scientific support, forecasting analytics and intellectual component; it takes place at the joint of the technological orders with highly increased complexity and rate of doing business, that demanding due economic and business environment in the country. What is at issue is the intellectual frame of the economy creation embracing the present day centres for communication and data processing, e-commerce, analytical and information-consulting services purposed for the information and intellectual business services and reducing the costs for business organization and doing, particularly small and medium one.

During the Soviet period the economic intellectualization was being successfully done through the network of the scientific and technical information, where highly skilled specialists prepared analytical reports for the scientists, managers, patent workers. That allowed to keep abreast and monitor the trends in the products, technologies and markets development. Abroad, new markets seeking and operations diversification were done mainly through innovative firms created within the major companies which were oriented to the manufacturing and self-promotion in the markets of new products and technologies.

Growing complexity of the economy demands a constant growth of its information and intellectual component along with the systems created for the inter-organization information interaction. This trend has been clearly revealed in the 1980s. At that time in the USA about two thirds of the wages were spent for the IT specialists, and one third of the equipment acquired in 1984 were computers and related devices. Earlier, in 1970s the academician V.M.Glushakov formulated the theory of the information barriers in economic management. He put forward an idea of the national network of computing centers and intellectual frame of economics – the national automated management system (OGAS).

The idea of the OGAS system was based on the fact that just quantitative growth of the computing potential can result in some significant changes of the management and labour productivity, provide certain progress in the organization and work efficiency of the administrative personnel. Of fundamental importance is the possibility to have the information

systematized and analyzed for the purpose of the decision-making process optimization. One of the OGAS priority subsystems is the dialogue planning system DISPLAN, which dynamically integrates the sectoral and republican plans in a dialogue mode. These ideas are still relevant.

The branch of intellectual business services is that part of economics which nowadays is the main motive power forming new markets and overcoming the entropy of the traditional ones. The material basis of new economics is the information structure including the data processing and information and consulting services centres.

Consulting as a management tool

Management structures are traditionally considered as mainly current tasks of static nature, but not dynamic. They are treated as a given set of line and functional services, originated in the 1930s, disregarding the new tasks and ways of development. The emphasis is generally put on the differentiation and specialization of functions, but not on their integration and interaction as for their common goals. However as soon as the objects and management processes complexity rises, respectively rises the role of not separate services (technical, economical, production and supply, etc.), but of their interaction and coordination. Multiple aspects of the enterprise operational environment should be taken into account as that demands multiple and different types of management. Perhaps the most important lesson of the long practice of the up-to-date information technology introduction is the strong recommendation not to automate the outdated ways of working. At the same time the management system should ensure the quick production changes depending on the market demands. In economics, like in nature, in the course of evolution survive not the strongest, but those who can quickly adapt to changes.

It should be kept in mind also that volume of management information is so large that it demands the intellectualized processing. As a market response, different information and consulting services arose to meet the economic demands. In the developed countries they were formed in separate sectors, for instance, in the US agriculture. There appeared a notion of the economic consultancy support and then a consulting services sector. In Germany, 3 market and management specialists fall per one employed in the production, in South Korea there are over 10 thousand independent consultants in economics, not to mention the information and analytical services of major enterprises. They analyze the market situation, make forecasts, estimate the risks. Demand prediction and the ability to join the products and markets are the standard problems for both the manager and the investor.

At the same time the information and consulting services are a key factor of the reasonable economic cenosis formed by gradual and consecutive transformation of large enterprises towards a balance of small, medium and large economic entities, higher level of their self-sufficiency and mobility. It is important that market self-control mechanisms were enabled, the joint programmes of the small enterprises, state and big business were co-financed, based on the mutual beneficial and complementary principles. In the market of the economically advanced countries there are a lot of consultants helping to shape a project, get better conditions for its realization, prepare the materials, interact with the investors, as well as there are mediators assisting in finding the right people. Because often the businessmen don't think much about the business prospects. The start-ups analysis of the Silicon Valley shows that business plans as a rule never work and the investors are more interested in the general idea of the project and why it should go off. According to the researchers, only 30-40% of the businessmen have a very general idea of the possible application of their development.

Traditionally the scientific and technical aspect of many Belarusian technologies is considered to be their strength as they are based on the original, truly innovative ideas. Yet their market component is not defined concretely and thus it needs to be improved. The lack of the clear understanding of the project promotion methods and its economic design create illusions about quick and great profits. The general problem here is a bad understanding of the market and its niches for new products. Serious investigations are needed on a steady professional basis.

Many developers have no idea as for the required efforts, time and resources to realize their projects. Other skills and specialists are needed for this purpose. Knowledge and understanding of the markets are the key conditions to form and do business at the present. It is mostly related to the high-tech industry as the specific character of its product demands that both marketing analysts and managers had a good understanding of this advanced technology product details. As a result, of greater importance becomes the Big Data Analytics which is called now the Data Science. There appeared the specialists who study how to get the data and transform it into the information resource. Also there was created a network of companies performing intermediary services between the administrative bodies, enterprises and research institutions. This work is a constituent part of the intellectual frame of the economy.

In the developed countries, there is a network of the consulting centres, the body of the specialized managing companies is expanding, state and private business supporting agencies have been formed. Of course, such a system was establishing during decades, and we need time to pass this difficult path towards it. The most important thing is to define the state policy of the consulting branch and

mechanisms of its interaction with branches and enterprises. The work on the situation analysis and ways of national economic development shouldn't be handed to the foreign outsourcing, as the economic and management consulting is a factor of national security.

Reduction of costs and "shaping" as the core of the structural reforms

Economy is constantly developing like the complex ecosystems and is subject to the rules of cenology. Its transaction costs may reach 40% and more. The analysis of the commodity markets and consultations on doing business by small enterprises is a possible way to reduce the non-production costs, which are estimated to reach 10% gross proceeds in Belarus and Russia, when abroad it is not higher than 3,5%. According to the Higher School of Economics, over 70% of those willing to start the business in Russia, fail to do that. Among the main obstacles are the following:

- bureaucratization, i.e. a great number of documents and long time for problems needed for their consideration;
- financial problems, e.g. unavailability of obtaining credit or investment problems and excessive taxation;
- poor state support (imperfect legislation, low financing of small business), also the high rental cost or problems with finding the market place;
- poor knowledge among the businessmen: inability to find the niche, problems with contractors and skills of the personnel.

As a result, according to the experts of the Oracle Capital Group (OCG), in the activity rating Russia takes the 8th place, ahead of almost all Western Europe, but in the quality of the institutional environment and state of the financial market rating it takes the 121st line, and by indicator of the credit availability it takes the 104th line. It means that the main problems of the country's development are related to the institutional environment and quality of the state and corporate administration, that in their turn depend on the services rendered to business system. About 95% of Russian start-ups stop operating during the first year. The business environment optimization is the most important factor of the SME development, which are factors of growth and greater stability of national economies. Thus, in the USA over 20 million of sole traders who have no employees, produce today the products for over 1 trillion dollars (about a half of the Russia's GDP).

New institutions of the information and consulting service and state development agencies are the material basis of the business environment simplification. Their formation is the point of the institutional economic reform, much spoken about by the IMF experts. Giving recommendations on its improvement through privatization and lower government control, they say nothing about the preformed mechanisms of the effective interaction of the businessmen with markets, state and with each other. As a result, the intermediary, trade and primary business is developing at accelerating rates, but not the manufacturing which requires analysis and concentration of resources.

At the moment we use the inertia of intellectualization laid by the Soviet research institutions, design departments, information and patent agencies. Yet the economy demands new standard of business services and management. The actual numerous marketing structures are not able to remove these shortcomings as they are aimed mainly at the sale of the finished products, yet during the periods of crisis, the forecast and effective management are of greater demand. At the same time the competition is going not for the redistribution of the market share, but for company, branch and economy in general entering the empty "blue oceans" of unsatisfied demand. It's just the strategy of the free "oceans" that is considered by the modern theorists of competition as the most perspective. But to gain this goal, the professional analytics of the market situation and dynamics is needed.

The problems of development is the issue to be dealt with by the special structures subject to the state administration. The economy's management needs gradual and progressive transformations to balance small, medium and large enterprises, their independence and mobility. Their correlation in the countries with sustainable development (Germany, Denmark, France) is he following: 70/22/8%. Such correlation enables to involve maximum citizens in the active business life and ensure the economic stability. In South Korea one of the popular slogan is: "Small business is a driving force of the economic growth". For this economic segment the new technologies are developed by the specialized institutes and centres, as well as by the corporation of industrial small business.

To bring the Belarusian economy closer to the reference correlation, it is necessary to form the state and private agencies for SME and investment development through different services provided to them: legal, estimating, marketing, staff recruiting, etc. At the same time the credits should be available to the manufacturing companies, and the specialized agencies would contribute to this. According to the World Bank, which studied the similar companies work in different countries, each dollar invested has near 200 dollars of direct investments. This is the result of the professional decision-making on the use of resources.

I think that main point of the structural reforms is "the shaping" of large enterprises and branches, but not their privatization. According to the world practice, the optimal employment volume in large companies is 700 workers, the rest manpower work by outsourcing, as

the spiral growth pattern puts it which was developed by the Cambridge professor Carlota Perez. This concept is related to the large modernized clusters formation based on the quickly growing economic sectors or branches, which products are in actual demand. That means that to develop the national economy successfully it is necessary to start using the "natural innovations" potential, to pick the "growth points" and ensure their synergetic interaction. At present, from this point of view, Belarus can consider the following sectors: agriculture and agricultural engineering, education and health care, building, agrarian tourism, intellectual business services, including programming.

So to have new opportunities for development, it is necessary to be based on the "new economy" segments: information and analytical services, management companies for clusters formation and operation, network methods of the enterprises interaction.

Measurement and the "new economy" role evaluation

Since 1999 the American Information Technology and Innovation Foundation has been calculating the "new economy" index of the states which indicates how a territorial entity can meet the challenge. This index uses 25 indicators in 5 categories: workers' skills; globalization, to estimate the state involvement into the regional and world economic relations; economic dynamics, to show the quick developing start-ups or individual segments; the rate of the economic informatization and the innovation potential to estimate the expenses for the R&D and groundwork for new products and technologies creation.

The top five states traditionally include Massachusetts, Delaware, California, Washington and Maryland having the highest number of universities and research laboratories along with the consulting companies, i.e. the highest rate of the human capital development. Consequently, those regions have the most sustainable development even during the crisis periods, where high-tech jobs and skilled agents rendering business services in different spheres (construction, design, marketing) networks are being created. At the same time it is a ground for the small business promotion and large enterprises competitiveness growth.

The "new economy" layer is devoid as yet of the clear formation concept, the mission and goal of the business support system is not clearly defined also, that's why there is a shortage of structures helping the large and small business to develop effectively and fully. Complex systems can't be managed in a simple way, can't be borrowed from outside, they should be elaborated at home in view of the national economic features.

At present when preparing and realizing the measures on the monetary stimulation of economic growth, the following aspects are not being considered in full:

- first, low number of the economic entities to have the synergetic effect of the business financial support (the number of the large, medium and small enterprises should have a correlation 8-22-70 respectively);
- second, poor business environment due to a low number of the information-consulting and management companies ("capillary system" to convert money into the competitive product);
- third, the quality of the management institutions, their improvement, fine adjustment of every element of the control system. It is a more complicated task than giving preferences and financial support to small business.

In the first stage of the reforms there have been formed the state power vertical line (line of command), systems of the finance accumulation and distribution, business security. Unfinished is the layer of the production enterprise system support. Therefore we need a national programme to form the consulting infrastructure, specialized agencies of the management companies. They can be established on the base of the state and commercial banks, turning them partly from "credit factories" to the development centres. In fact, there can be formed a new growth model and made a leapfrog, or as the academician V.M.Glushkov put it, "to overtake not catching up". ■

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SYSTEMS OF THE CONTINUOUS IMPROVEMENT ACTIVITIES OF ENTERPRISES BASED ON THE KNOWLEDGE MANAGEMENT

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Lately the specialists in organizational development often talk about a continuous improvement of the activity of enterprises (CIAE). It is connected with the fact that different management technologies that were used earlier for reorganization, merger or strategy change, become everyday instruments of operational management. Strategic plans were developed for the period 3–5 years recently, but today one can often here about their short-term nature or even rejection of them. It means that companies should change not once in 3–5 years, but permanently, not at the strategic level of management, but at the operational one. There are many approaches to CIAE, but they are used not quite effectively in the post-Soviet space.

The aim of this article is to reveal the common base in different approaches to CIAE and to show why knowledge management can be used as a base of different technologies of CIAE in domestic organizations.

Why is there a need of continuous improvement of the activity?

More often the reasons of turning to CIAE are the following:

- Globalization led to a sharp increase in competition. In order to work effectively one should take into account the actions of competitors in the whole world, and this means faster change of goods and services, relationships with clients and contractors.
- Constant updating of assortment leads to the need of using new technologies that increase the production effectiveness, which in its turn is accompanied by restructuring of technological and business processes.
- Many companies use one or two competitive strategies described by M. Porter and oriented either to improvement of industrial processes with the aim of reduction of costs or to development and introduction of innovations. As long as the life circle of goods is constantly reducing, organizations have to increase the speed of change in their activity.
- Globalization affects also institutional environment – states, interstate formations, legislative sphere, infrastructure and so on. The changes here happen faster. One can recall the amount of critical events in the sphere of Belarusian business over the latest 5 years. This makes organizations develop their ability to respond quickly to environmental changes, behavior of customers, the work of contractors and so on.
- Investors' approach to the building of business also changes in the new conditions. It gets a short-term nature, and when business gives the expected results it can be sold or the minimal share of investors in the share capital is left. The investment business itself becomes the technology on creation, development and doing business.

All these things lead to the idea that business entity management is the single merely a system stream of its improvement. For continuity of this process it's necessary to use such model of organization which significantly simplifies its monitoring, identification of bottlenecks, generation and implementation of effective management decisions with control of diversionary factors [6]. As a result the concept "management" means a continuous improvement of the work of company. The problem is to find adequate instruments and technologies of such management.

The concept of the activity continuous improvement

This concept was formulated for the first time in the Japanese production philosophy Kaizen, focused on the traditional eastern ideas of self-improvement [9]. All basic western approaches to management come from this system: the system of total quality management, economical production, 6 sigma and so on [7, 11].

The ideas of continuous development became popular, because in conditions of global competition the companies need not a separate one-time change as reaction to internal or external changes, but the system of continuous improvement, which enables to see the system of organization as a whole and to make not very expensive, but effective operations in the key points of company. In the new conditions the concept of proactive behavior of organization becomes perfect. It can make organization the initiator of market changes.

Among approaches to creation of the systems of continuous improvement there can be specially distinguished the knowledge management (KM) [1, 5, 10]. Initially it was viewed as an instrument to increase the effectiveness of operational activity of companies, but it has become an independent approach to the management of innovative company as a whole.

Idea of knowledge management

Knowledge management is conscious experience of successful activity, which can lead to significant increase of effectiveness of the whole company. It is called management because managers determine the areas of work and plan the result. They should know it to understand whether the costs for knowledge management will be paid back.

For knowledge management the following things are needed:

- Effectiveness monitoring systems;
- Procedures on the search and implementation of solutions on increase of effectiveness;
- The ways for transfer of experience – corporate regulations, standards, instructions, techniques, general specifications and so on.

Information technologies promoted the spread of KM. It helped to transfer and structure the knowledge faster. But then the priorities changed due to a huge number of excessive information: KM is oriented to the new knowledge and its generation instead of adaptation of ready knowledge to a new situation, because introduction of the ready knowledge is almost equivalent to creation of the new knowledge.

Many scientific investigations are devoted to the factors that influence success of organizations, which is expressed through increasing cost of shares [12, 13]. The main motive in this approach was connected with success of different hi-tech companies and intelligence of their staff as a key asset. Then different methods of management of intellectual capital were developed (from simple accumulation to inclusion in connections with other kinds of capital in order to form effective chains of creation of consumption value of organization).

In spite of the fact that the management of intellectual capital and knowledge is viewed in the modern literature as one chapter, it's early to say that they form a single concept. These techniques are used for different aims (increase of effectiveness or the company's value), but that aims are situated at different system levels of organization analysis, and the management of knowledge can be regarded as sub-aim of intellectual capital management. The cost of company becomes the measure and frame of all activities on increase of its effectiveness.

Management of knowledge as technology of the CIAE

In practical terms the KM reduces in the first variant to exchange of experience among the staff through a corporate portal. This exchange can be organized (formal) or not organized.

The second variant means creation of different working groups – interdisciplinary, network, virtual ones that eliminate the problems in the company. The main difficulty in this approach is to choose really serious tasks for business, because they are often replaced by particular technical problems. At the higher level the instruments of KM integrate into the system of management as a whole and convert the standard methods of management into the methods of organizational training, that is generation and learning of the new experience. In this complicated structure with different and changing human content the management system should allow to generate, select and transmit the most successful practices for the whole company.

The main difference of knowledge management from other approaches to CIAE is that it's oriented to a regular use of management procedures and processes and doesn't pay enough attention to corporate culture (as in Japanese enterprises), though its role is quite significant.

Main approaches to integration of knowledge management into the system of company management

Intellectual capital management

The meaning of this approach is setting parameters to assess the state of intellectual capital (IC) of the company. "Intangible assets monitoring by Sveiby" [13] is actively used to determine it. The intellectual capital itself is divided into the capital of external structure (relationships with customers and contractors, brand value etc.), internal structure capital (technologies, business processes, providing units etc.) and human capital (staff qualifications). The monitor contains quantitative parameters (indicators) that help to assess the IC dynamics. In each of its forms the parameters are differentiated into such groups as "Growth", "Renewal / innovation", "Effectiveness", "Risk / stability". The use of this instrument involves control of intellectual assets and development of its components.

There are other methods of IC management, but the model "the process of intellectual capital

management" (ICMP) developed by the British company Intellectual Capital services Ltd., is the closest to practice [12]. The main principle of this method is that all resources of the company are considered from the point of view of their influence on creation of customer value, and the latter is considered as transformation of resources from a certain form to another one. This method is defined by the business model of the company. Improvement of its activity includes different measures promoting construction of intellectual capital management process. This approach is actively used in European countries, because it allows doing the following:

- To connect certain regular management activities with the final result – increase of the company's value;
- To create clear and logical system of registration of intellectual capital and human resources;
- To form optimal business model (the model of chain of consumer value creation) depending on availability of intellectual resources;
- To connect the theory and philosophy of intellectual capital with empirical practice of organization.

The system of balanced indices

The system of balanced indices developed by D. Norton and R. Kaplan is the most widespread and practically used [8]. Its main advantage is that it shows the interrelation of such components of any commercial organization as the following:

- Financial goals;
- Customer needs and quality of goods and services;
- Technological and business processes;
- Measures on education and development of the staff.
- The main task in building the system of balanced indices is to establish a causal link between all activities that lead to achievement of financial goals.
- This sequence can be represented as the following:
- Setting financial goals for a certain period;
- Studying the needs of clients and consumer quality of goods and services of the company;
- Changes in production and business processes for production of goods of the required consumer quality;
- Determination of the need for competence necessary to change production and business processes, educational and development activities.

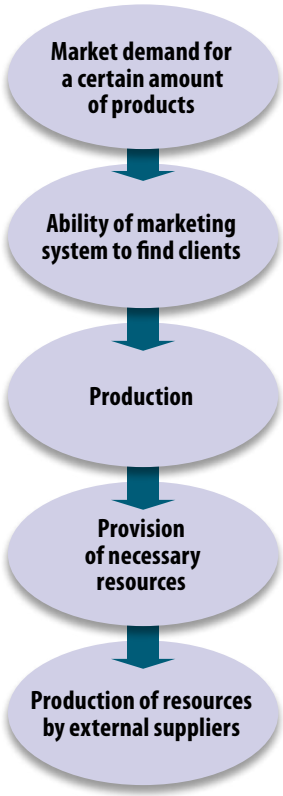
Then there should be developed a list of parameters for each direction. They are the performance indicators for all activities in general. They are necessary to control the progress of organization. After identification they cascade to the lower levels turning the private goals of departments to sub-goals of the whole company.

Preparation of the system of balanced indices means working out the strategic map with the goals and activities to achieve those goals. They are fundamental being the base for all changes in the current production and business processes. But unlike the approach based on intellectual capital management, the final task of all measures here is to achieve specific financial goals, not increasing the value of organization. The system of balanced indices is extremely practically oriented approach.

In Belarusian enterprises this practice is complemented by setting a list of tasks for managers on all components for different periods of strategic planning. There are many companies already that introduced the system of balanced indices, but mainly it is connected with clear parameterization of activity of departments. There are still few examples of functioning of knowledge management systems within the system of balanced indices.

Removal of system limitations of organization

Israeli scientist Eliyahu Goldratt created the theory of system limitations (TSL). He viewed organization as a system, which has a key limitation [3, 4]. The whole system was defined as a value chain. For example, the following sequence of elements:



A weak place in a value chain limits its effectiveness as a whole. Removal of one system limitation significantly increases the effectiveness of the whole system, but it leads to appearance of a new limitation. For example, increase in sales can lead to production problems (insufficient output) and so on. Continuous improvement means continuous detection and removal of system limitations. These processes involve spending small amount of resources while the effect is significant. It explains the popularity of Goldratt's elaboration.

What is the role of knowledge management in TSL? It is not distinguished as a separate discipline, but the approach itself can be referred to the knowledge management due to the following:

1) The main methods of limitation theory (Current reality tree, Diagram of conflict resolution, Future reality tree, Transition tree, Plan of change) are directed to formulation and solution of intellectual tasks connected with detection and removal of system limitations, that means generation of the key management decisions.

2) In spite of the fact that in literature there are mainly occasional projects on search and detection of system limitations, the practice of TSL means regular work on their search and removal, which is impossible without specially organized regular activity (knowledge management).

The theory of limitations together with TRIZ-functional value analysis and System-mental-activity methods has many followers on the post-Soviet enterprises, including the domestic ones. Since Goldratt initially used his approach for work with steel-casting enterprises, his method is more popular in the production sphere. But there are already examples of using TSL in other spheres.

The approaches mentioned above have some common elements that make the practice of continuous improvement almost identical. These elements are:

- Parameterization of results taking into account the factors that lead to receiving/not receiving the desired result;
- Building of organization value chain according to the logic of causal links in transformation of different forms of intellectual capital into other forms;
- Financial result is considered to be the criterion of enterprise ability to understand and satisfy clients' needs;
- Functional (not cost) approach to analysis of intellectual assets; assessment of their cost on the base of their use;
- Setting the key parameters of organizational effectiveness as a whole and their connection with operational indices of departments.

Bottlenecks in the CIAE concept implementation

Domestic enterprises have extensive experience in building the systems of continuous improvement of activity and knowledge management, so we can talk about typical problems in implementation of these approaches.

Knowledge management is often not connected with the key tasks of organization. One mistake in management decision can devaluate the effect of KM at the level of specialists.

- Introduction of KM and CIAE instruments into the work of managers is more effective than at the level of ordinary employees, though it's oriented initially to the ordinary staff.
- The effects of KM and CIAE have a short-term nature, because they are viewed as projects (not as processes) and stay at the focus of attention of managers for a short time.
- Implementation of the systems (first of all quality management) is formal, and it doesn't influence significantly the improvement of activity.
- Companies do not define the owners of CIAE process. So this process becomes uncontrollable and finally winds down.
- The culture of widespread improvement (as in Japan) is based on collectivism, which is contrary to the western individualism and innovative orientation of business model generally.
- Finally for significant increase of effectiveness the KM and CIAE lack the following things:
- To transfer this process to the level of the board of directors, that is to the level of higher and line management.
- Active use of diversionary analysis instruments due to increasing risks of innovative ideas [6].
- Including the instruments of work with business models into the CIAE process to make business model the subject of management.
- In this case the algorithm of CIAE system can be the following:
- Determination of business model as a chain of creation of customer value.
- Setting the parameters of effectiveness of the whole chain in general and each function separately.
- Setting the target parameters of effectiveness for the whole chain of customer value creation.
- Creation of the monitoring system of appearing limitations in the system of organization.
- Development of the procedure and technology of removal of limitations.
- Formation of the system of management of value chains including relationships with suppliers, contractors and clients.

Our practical experience of consulting support of the process of creation of knowledge management systems and continuous improvement systems shows that exactly this sequence of actions helps to make an effective CIAE system.

Modern company has to solve many problems. It's not always clear which one of them is the most important. That's why creation of the system of effective management should start with the ability to define key tasks and solve them successfully. In case of turning this process into the subject of continuous improvement this will reduce the dependence of organization on individual qualities and competence of the manager and increase the effectiveness of organization generally. It will help to transfer a positive experience not only to the companies of the same sphere, but also to the whole country. ■

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PLANT BIOTECHNOLOGY AS A WAY OF THE RATIONAL USE OF BIOSYNTHETIC CAPACITY AND PLANT BIODIVERSITY

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A distinctive feature of modern plant biotechnology is that most of its sections are based on the use of plant objects in vitro. These objects can be plant tissue, organ and cell culture, a sterile test tube plants or isolated protoplasts (fig.1). Plant biotechnologies can be classified by the products they produce: vegetative production for ecology, agricultural, forestry, horticulture etc. and producing secondary plant products for industrial purposes.

Biotechnological collections are created for ecological purposes, to store and reintroduce rare and endangered plant species. Some of these species (especially medicinal species) are poorly propagated by seeds. Plant conservation is a global world problem that can be solved at the junction of biotechnology and wild biodiversity conservation. Plant conservation biotechnology is a modern and interdisciplinary subject, by which the tools of modern biotechnology are applied for plant conservation. It is important that these techniques must not replace traditional ex situ and in situ conservation methods. A wide range of biotechnological methods are now utilized including: 1) tissue culture techniques; 2) molecular genome analysis; 3) immunological diagnostics; and 4) cryopreservation protocols for the collection, characterization, disease indexing, propagation, patenting, storage, documentation and exchange of plant genetic resources.

Plant biotechnologies (from plants in the test-tube to protoplasts) are directed toward creating new plant forms, simplifing selection processes, and effectively reproducting and improving valuable genotypes. The first group (test tube biotechnology) is the most numerous, it includes biotechnology of haploids and dihaploids (androgenesis, gynogenesis), obtaining and cultivating the hybrid embryos (overcoming postgamete and pregamete incompatibility), various methods of cellular selection (including somaclonal variation), somatic hybridization and genetic engineering as well. The second group, (protoplast biotechnology) is represented by the various ways of clonal micropropagation and plant recovery. Industrial biotechnologies are aimed at the production of plant products, using cell cultures and occasionally plant organs (primarily roots).

The plant biotechnological collections

Many medicinal plants are rare and endangered species that are important not only for environmental aims (species conservation), but also they have considerable economic significance. To preserve unique genotypes, it is important to stop formation of cell populations in vitro in the beginning of the plant cell cultures. Otherwise due to somaclonal variation it's possible to lose the valuable properties of the varieties. In this case the test tube individuals, plant organs or tissue can be used as the storage objects.

If it's necessary to preserve not only a specific genotype but also a gene pool, then it's possible to conserve them as morphogenic or embryogenic cell cultures. The cryopreservation of the embryogenic

cell cultures of the endemic species of Dioscorea caucasica Lipsky and Dioscorea balcanica Kosanin are examples of the Timiryazev Institute of Plant Physiology collection. After cryopreservation the cultures retain the ability of somatic embryogenesis and can fully regenerate plants. The collections of the plant cells and organs cultivated in vitro successfully function abroad. In addition, the cryobanks have been organized where the samples of a plant material of different taxonomic groups are kept in liquid nitrogen. Most of the samples are rare and endangered plants and they are preserved as a national treasure. There are a number of the medicinal plants here, for example, Scutellaria baicalensis Georgi, Scutellaria lateriflora L., Scutellaria racemosa Pers. There can be mentioned German collections among European ones. More than 700 samples of different cell culture lines belonging to 80 plant families are supported here. In addition most of them synthesize pharmacological important secondary metabolites. There are many repositories in France, Italy, Spain, Belgium, Poland, Romania, Japan, India and other countries. Russian collection of the cell cultures was established in the Timiryazev Institute of Plant Physiology, Russian Academy of Sciences, in 1978. Nowadays it includes two specialized repositories which have the higher plant cells and the genetically transformed plant roots. In general this collection has about 100 different cell culture strains and lines.

The Central Botanic Garden of the NAS of Belarus was awarded with a Certificate of the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus for the collection of aseptic cultures of economically useful plants in 2005. Some medicinal plants such as Agastache rugosa (Fisch. et Mey.) Kuntze, Melitis sarmatica L., Digitalis purpurea L., Digitalis lanata L., Digitalis grandiflora L., Ruta graveolens L., Scutellaria baicalensis Georgi, Polemonium coeruleum L., Salvia officinalis L., Lithospermum officinale L., Stevia rebaudiana Bertoni, Hipericum pat-

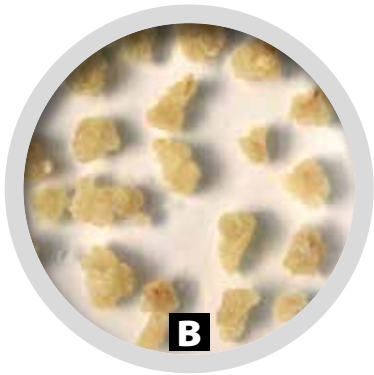

Fig. 1.
Cell culture of Agastache rugosa (Fish. Et Mey) Kuntze (A) and milk thistle (Silybum marianum L.) (B)

ulum Hidcote, Artemisia hololeuca L., Silybum marianum L., have been added to the collection 2011 – 2012 and some species and varieties of lilacs (Syringa L.), rododendron (Rhododendron L.), blueberry (Vaccinium corymbosum L.), Dactylorhiza Neck. were also included (Fig. 2).

As a rule, the depositing of the collection samples is done with slower plant growth, when division and metabolism of its cells are low. It allows changing the nutrient media less than usual and therefore reducing significantly the cost of maintaining collections of the vegetative propagated plants. This technique is widely used throughout the world because it can effectively conserve all clones and varieties of valuable medicinal, fruit, berry and ornamental crops.

Cryopreservation is widely used by members countries, including Russia, to lower the expenses for the long-term maintenance of the valuable plant material collections and to reduce the probability of loss of the samples. The developed conservation methods are used for more than 200 species cultured in vitro on non-orthodox plant seeds and tissues [1].

Application of the biotechnological methods for creating new forms

A unique and effective way to enhance genetic diversity is the use of somaclonal variability along with androgenesis, gynogenesis and embryoculture. It is known that plant cell cultivation in vitro is able to cause the same genome rearrangements as chemical mutagens or various types of radiation. The regenerated plants from those cells retain these mutations. Induced mutagenesis can be used in order to increase the degree of genetic diversity, but this process using somaclonal variability is non-directional and most often variations appearing during these cultivation processes have no practical significance. However among the somaclones (modified regenerated plants) individuals can be selected with useful features. Thus, sugarcane individuals resistant to the Fiji virus, a yellow spot and a downy mildew were identified. Wheat somaclones having enhanced cold tolerance have been selected in Hungary. Medicinal regenerated plants with an increased biosynthesis of biologically active substances (BAS) have been obtained in the Ukraine. The biotechnology cell selection scheme of Agastache rugosa (Fisch. et Mey.) Kuntze and the scheme of obtaining somaclonal genotypes with the high content of biologically active substances (Fig. 3) have been developed in the Department of Biochemistry and Plant Biotechnology (CBG NAS of Belarus). The biochemical analysis has revealed a high content of the flavonols and phenolic compounds in selected regenerates; the highest values were identified in the 11th somaclone. The RAPD + ISSR marker system was developed to differentiate A. rugosa genotypes and to estimate the

Fig. 2.
Aseptic plant of milk thistle (*Silybum marianum L.*) from the sterilized seeds

Fig. 3.
Culture in vitro of Agastache rugosa (*Fish. Et Mey*) Kuntze

Fig. 4.
Several stages of Syringa micropropagation in culture in vitro, cultivar Pavlinka and ex situ Syringa plants

genotype discreteness of modified individuals from the original form and to identify somaclone 11 as the most genetically remote from initial genotypes [2].

Rapid and efficient reproduction of valuable genotypes (clonal micropropagation, CMP)

After the selection of successful genotypes there is a problem of their conservation and practical usage. The clonal micropropagation plant technology was established on the basis of the study of experimental morphogenesis in vitro. Today this technology has become successful in commercial agricultural fields in many countries.

The clonal micropropagation can be produced in different ways. The most common ones among them are:

- micro cutting of test-tube plants;
- the induction of microtubers and microbulbs;
- the isolation of buds or meristems with their subsequent cultivation in the media with phytohormones and induction of shoot.

A new technology is compared with the traditional methods, but its advantages are higher propagation index (to 100 000 plants per year versus 5–100 individuals for the same period), saving areas occupied by mother and propagated species, and the breeding of those plants which do not reproduce or propagate in the usual way.

It is principally important that clonal micropropagation is often accompanied by the improvement of samples. The small size of the explant (part of the plant used as raw material), and its surface sterilization and aseptic (sterile) culturing on sterile nutrient media prevent contamination from nematodes and bacterial pathogens. This method with the thermo- and chemotherapy combination helps eliminate harmful viruses, viroids, and mycoplasma.

Clonal micropropagation is widely used for obtaining a large quantity of planting material from medicinal, ornamental and vegetable crops and is also an excellent way to vegetatively propagate valuable hybrids and to preserve a heterosis effect.

The industrial technological lines for breeding by in vitro culture methods species and varieties of lilacs (Syringa L.) (Fig.4), rodorendron (Rhododendron L.), blueberry (Vaccinium corymbosum L.) and etc. have been developed in the CBG of the NAS of Belarus [3].

Certification and molecular diagnosis of genetic resources

Documentation and certification of genetic diversity are essential in formulating genebank conservation programs, whether in-situ or ex-situ. Molecular markers play a significant role towards these goals. They provide information ranging from diversity at the nucleotide level to gene and allele frequencies (genotype information), and to distribution of genetic diversity, and population structure. Such information can be utilized for devising a proper conservation strategy and management of genebank and collections [4].

DNA based markers are neutral and independent of any environmental cues or developmental stage (temporally and spatially independent). Thus DNA based markers have an enormous advantage over biochemical markers for cataloguing of germplasm and genetic diversity analysis.

Genotyping and genetic certification are carried out in the CBG to assess the genetic diversity of populations, samples, and varieties of collections. It means that each individual or form is checked on the presence or character of the display of the set of molecular genetic markers.

An integrated approach based on PCR with random (RAPD) and microsatellite (ISSR) primers has been proposed for the assessment of genetic diversity and for the certification of varieties of agronomic and medicinal botanical collections in the department of plant biochemistry and biotechnology of the CBG.

Specific markers have been developed for the formation of unique genotypic profiles (which are the basis of the passport) of the valuable cultivars of the following

Table 1.
Multilocus genetic passports of highbush blueberry varieties

* - Bold marked variety specific (unique) locus; underlined loci occur in all varieties involved in the study

Bluecrop	
	
Primer	**Amplicons**
OPA-08	$OPA08_{310}$, $OPA08_{325}$, **$OPA08_{505}$**, $OPA08_{590}$, **$OPA08_{1075}$**
OPA-09	$OPA09_{325}$, $OPA09_{435}$, $OPA09_{475}$, **$OPA09_{650}$**, **$OPA09_{685}$**, $OPA09_{825}$, $OPA09_{1060}$
OPA-20	$OPA20_{510}$, $OPA20_{540}$, **$OPA20_{555}$**, $OPA20_{675}$, $OPA20_{760}$, $OPA20_{985}$, **$OPA20_{1120}$**, $OPA20_{1415}$
UBC-818	**$UBC818_{225}$**, **$UBC818_{300}$**, $UBC818_{375}$, **$UBC818_{465}$**, $UBC818_{530}$, $UBC818_{615}$, $UBC818_{660}$, $UBC818_{1210}$, $UBC818_{1775}$
UBC-824	**$UBC824_{525}$**, $UBC824_{545}$, $UBC824_{630}$, $UBC824_{645}$, $UBC824_{670}$, $UBC824_{990}$, $UBC824_{1655}$
Bluetta	
	
Primer	**Amplicons**
OPA-08	$OPA08_{310}$, $OPA08_{325}$, **$OPA08_{505}$**, $OPA08_{590}$, $OPA08_{875}$, **$OPA08_{1075}$**, $OPA08_{1515}$, $OPA08_{2205}$, $OPA08_{2480}$
OPA-09	**$OPA09_{310}$**, $OPA09_{325}$, $OPA09_{500}$, $OPA09_{530}$, $OPA09_{565}$, $OPA09_{590}$, **$OPA09_{615}$**, **$OPA09_{650}$**, **$OPA09_{685}$**, $OPA09_{745}$, $OPA09_{860}$
OPA-20	**$OPA20_{300}$**, $OPA20_{510}$, **$OPA20_{555}$**, $OPA20_{675}$, $OPA20_{760}$, $OPA20_{820}$, $OPA20_{985}$, **$OPA20_{1120}$**, **$OPA20_{1250}$**
UBC-818	**$UBC818_{300}$**, $UBC818_{375}$, **$UBC818_{465}$**, $UBC818_{550}$, $UBC818_{570}$, $UBC818_{730}$, $UBC818_{880}$, $UBC818_{960}$, $UBC818_{1210}$, $UBC818_{1410}$
UBC-824	$UBC824_{440}$, **$UBC824_{525}$**, $UBC824_{670}$, $UBC824_{815}$, $UBC824_{990}$, $UBC824_{1350}$, **$UBC824_{1775}$**

collections: highbush blueberry (Vaccinium corymbosum L.) (Table 1 in Figure 5), amaranth (Amaranthus L.), Kuril tea shrub (Potentilla fruticosa L.), lilac cultivars (Syringa L.), species of fenugreek (Trigonella L.), milk thistle (Silybum marianum L.) and others.

A unique set of amplicons help differentiate the crop genotypes (varieties, shapes, types), and reference spectra conduct the verification of the sample collections in vitro for the genotype varieties.

The biotechnology of biologically active substances (BAS) preparation from plant material

Nowadays the plants and their biologically active substances are widely used in modern medicine. Of the greatest interest preparations with anti-tumor activity, adaptogenes, immunostimulants, cardiological and antimicrobial medicines. They all are prolong human lifetime and quality of life. In this connection the most important task is to find renewable phytogenic BAS resources, but gathering rare plants in wild nature represents an essential danger for their conservation. Plantation cultivation is often uneconomical and it is difficult to obtain initial plant material, especially for species which are hardly propagated by seeds. Biotechnology in its broadest sense explores its use across many fields of application, from the conservation of endangered species to the storage of economically important crop plants and to the industrial plant cell culture collections.

Higher plant cell culture can be an alternative method of raw plant material production for medicine, veterinary science, perfumery, and in food industry. The main point is to obtain biomass in large volume bioreactors in sterile conditions [5].

The main advantages of this method are: absolute ecological purity of cell culture cultivation; the possibility to obtain plant biomass with required characteristics independently of season, climatic and weather conditions; and high speed of biomass production – for example, 2 grams can be produced from one liter of medium per day (for comparison an amount of Panax root growth in plantation conditions is about 1–2 grams per year). One more advantage is the absence of pesticides, herbicides, radioactive substances and the other pollutants and the possibility to use standard equipment of microbiological manufactures (bioreactors, post fermentation systems, etc.). In some cases in vitro cell biomass exceeds the properties of the natural plant. The cell culture is considered to be irreplaceable in the case when we need to obtain raw material from rare and endangered species or from tropical medicinal plants species.

Genetic transformation by the wild strains of soil bacteria Agrobacterium rhizogenes is among the innovations of plant biotechnology for obtaining roots. These roots are able to grow for a long time on a simple medium without growth hormones.

Summing all up, the main directions in creating, maintaining, and utilizing biotechnological collections connected with BAS are:

- cryopreservation of medicinal genetic resources and deposition at low temperatures of in vitro plant material banks;
- plant clonal micropropagation (including a somatic embryogenesis) for selection development and to obtain high quality planting material;
- plant cell and tissue culture using for BAS production:
- biotechnology for industrial production of natural herbal remedies for various purposes.

Thus, biotechnology plays a major role in all aspects of plant genetic resource management, conservation, and utilization. Examples of sectors and industries include: aquaculture, forestry, horticulture, and the secondary products industries. More importantly, biotechnology is rapidly gaining the importance for the conservation of endangered plant species. ■

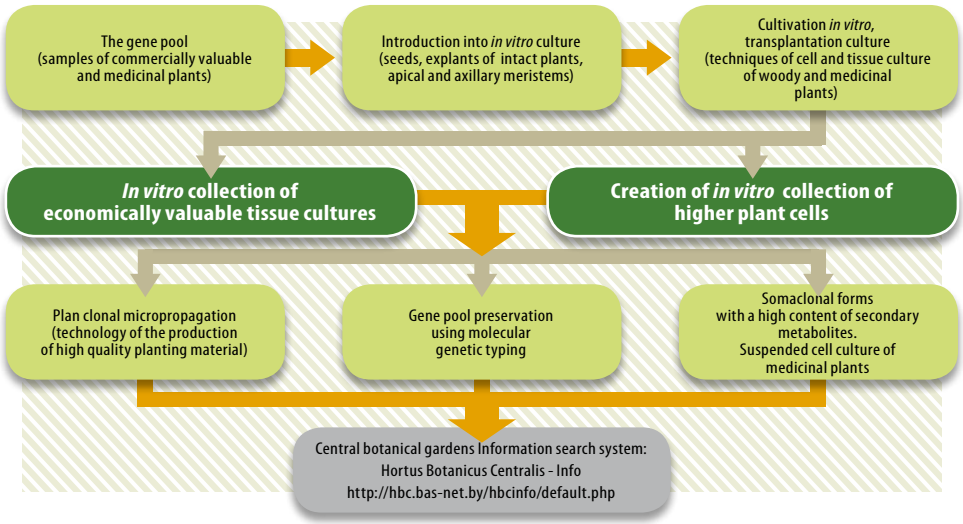

Fig. 5. Biotechnology scheme of creation and study of the CBG collections

Summary

The article deals with the characteristics of plant biotechnology, mainly concerning medicinal plants. Modern plant biotechnologies use plant facilities in vitro to produce sterile test-tube plants, to culture organs, tissues or plant cells, and to isolate protoplasts. Based on the final products, the biotechnologies are divided into two groups, the main technology group produces intact medicinal plants, and in the second group the end products are biomass cell cultures and/or phytochemicals. Thus, the aim of this article is to review plant biotechnology in its broadest sense and to explore its use across many fields of application: from the conservation of endangered species to the storage of economically important crop plants and industrial plant cell culture collections.

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