Alexander Chursin · Andrey Tyulin

Competence Management and Competitive Product Development

Concept and Implications for Practice

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Contents

Chapter 1
Introduction

The Monograph provides answers to a number of important questions concerning the national economic development, primarily talking about the high-tech industry; it's also about the creation and the expansion of new markets that is critical to sustain the GDP growth.

Today, competitiveness is viewed as a universal multi-level concept reflecting the competitiveness of products, enterprises, corporations, industries and even the entire economy as a whole. At the same time, the only mean to win is the market fight, which is won by the one who has the most modern knowledge, competencies and innovative developments, provided that the right strategy is chosen for the management of competitiveness. Further the Monograph is telling about the toolkit for creation of this strategy.

At the same time, the competition, one way or another, leads to an increase in the GDP of those countries that are entering the world economic leaders. The study of these processes allowed the authors formulating a fundamental law on the relationship of competencies with the emergence of new markets, as well as mathematical models to identify the core competencies, assessing the growth of the products competitiveness level depending on their application, and the assessment of the human potential which is the main source of an organization's competencies.

With the advent of new technologies (molecular biology, nanotechnology, additive technologies, etc.), new technological clusters are being created, therefore, in order to take the leading positions in the world, an enterprise is to be constantly improving its own technologies and creating or borrowing new ones. Only those companies able to create new, unchallenged mechanisms of innovation management and based on them would produce highly competitive products to widen the existing sales markets or create new ones, will be able to retain their leading positions in the economy.

The main principles of such a mechanism should be an integrated and gradual, but steady improve in competitive advantages. Complexity is understood as the possibility of managing the creation and development of new competencies, not excluding the cases of their spontaneous emergence due to the emergence and development

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of new knowledge. An efficient system of competencies management at enterprises of high-tech industries should become a key factor for increasing competitiveness and assist them entering the international market. The basis for the creation of such a system is the model of the corporate network of Competencies and Innovation Management Centers based on the application of Open Innovation mechanisms and the transfer of unique competencies and technical solutions that would ensure the high-tech companies sustainable development due to the improve of competitive positions in the world.

One of the functions of the Competencies and Innovation Management Centers is their systematic evaluation in terms of compliance with the world level of science and technology development in accordance with the algorithm developed in the Monograph that is the basis for the formation of a standardized industry information space with the purpose to transfer unique technologies and competencies. The proposed economic and mathematical methods for assessing the efficiency of the development of new competencies to ensure the sustainable development of high-tech companies and the architecture of information and analytical platforms for the implementation of simulation models for assessing new competencies can be used in the practice of corporations in order to improve their global competitiveness.

The study of theoretical and practical methods for managing the competitiveness of innovatively active enterprises has shown that it is necessary to implement measures to ensure sustainable economic development and improve the competitiveness of national products, and this requires the creation of institutional conditions and an information infrastructure for improvement of the economic interaction, the integration of enterprises and organizations with different core competencies, a broad involvement of external intellectuals resources based on the crowdsourcing.

The Monograph developed an economic framework for the industry innovation with the use of core competencies and unique economic tools to ensure the sustainable development of high-tech branches. It is shown that the economic stability of high-tech enterprises largely depends on the state policy in the innovation sphere, the mechanisms of pricing in science-intensive products, the impact of various kinds of internal and external risks (including geopolitical conditions), the implementation of programs to expand production, their investment attractiveness, venture activities, etc.

The subject of this Monograph are namely these issues and tasks of further development of the theory and practice of creating conditions for sustainable innovative development of the high-tech sector of the economy and increasing its competitiveness on the basis of creation and management of competencies.

The proposals and recommendations formulated in the Monograph can be of theoretical and practical interest for economists, analysts, government and business representatives.

Chapter 2
Theoretical Aspects for Using Competence as a Tool to Improve Corporation Competitiveness

2.1 Theoretical Basis of Corporate Competitiveness Management Through the Use of Competency-Based Approach

Economic and structural changes in the world in the late twentieth—early twenty-first century—the decrease in the manufacturing in the country's GDP structure, the rise in the mining operations amid the rising oil prices, the greater economy dependence on imports, the transition to a market economy, etc.—posed a number of new challenges to the country. In the first instance these challenges derive mainly from the commodity-dependence of the economy in the context of significant gap in the development of knowledge-intensive industries with the developed economies (USA, Germany, Japan etc.) Today it is extremely important to build a world-level scientific and production capacities, and to ensure the competitiveness of national products in the domestic and foreign markets. In this regard, it is crucial to find effective mechanisms for managing competitiveness and develop new tools for its improvement, particularly in strategically important high-tech industries.

The concept of competitiveness is complex due to its use at various levels of generalization and, consequently, the variety of approaches to assessing competitiveness. The interaction of factors that determine the dynamics of competitive environment remains the most controversial issue, therefore there is a justifiable opinion that it is impossible to say exactly what type of factors interrelation forms the competitiveness index (additive, multiplicative, divisible, mixed, or, possibly, nonlinear), and also what factors can best determine it. Undoubtedly, in different areas there are specific ways of gaining competitive power. In addition, these ways may change as economic relations develop, therefore the factors will vary, and the quantitative description of their relationship will differ.

As an object of discussion, the issue of competitiveness is especially popular in such research areas as international trade, economic strategy, the world economy, economic geography and applied economics, and economic analysis, etc.

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We can name the following scholars as the significant contributors to the development of "competitiveness" concept and were the first who started studying it: J. Schumpeter, who studied the institute of enterprise as a competitiveness factor in his work "Capitalism, Socialism and Democracy" (1942); American economists A. Sloan and P. Drucker, developing the concept of management as a key competitiveness factor (see, for example, A. Sloan's book "My years in General Motors" (1963) and P. Drucker's one "The age of Discontinuity" (1969)); P. Solow, who studied education, technological innovation and knowledge as the main factors of high competitiveness of the United States in 1948–1982 in his book "Technical Change and the Aggregate Production Function" (1957); M. Porter, whose research resulted in the development of the concept of five forces of competition, which allows describing the determinants that have the greatest impact on economic entities under the conditions of market competition.

It is critical to underscore that the first researchers of the competitiveness management problem regarded it as a specified criterion conditioned by various internal and external factors.

Later on, the scholars in the course of further research produced the idea about the possibility and necessity of results-based competitiveness management, which led to the emergence of a variety of approaches, within which it became possible to justify the plans of achieving the required level of competitiveness.

Approaches to the competitiveness management have undergone significant changes in the course of development and evolution of world views on this issue (Table 2.1).

It should be noted that in the late 1960s, the twentieth century, there was a gradual shift in priorities, increased attention to the internal factors of the organization development on the basis of more rational use of available resources. Most of the modern concepts of the organization development are aimed at optimizing internal resources.

On the basis of data contained in Table 2.1 we can deduce, as it was noted in various works by foreign scholars in twentieth century, that organization competitiveness management is significantly dependent on effective knowledge management within the organization taking into account the specific features of an industry.

Issues of sectoral competitiveness were addressed in the works of D. Clavens, M. Porter, A. Smith, A. Strickland and A. Thompson, K. Fisher, R. Flanagan, R Schoenberg et. al.

According to A. Thompson, and A. Strickland competitiveness factors include: quality and technical characteristics of products; image of industry organizations; production capacities and innovative opportunities that the organizations of the industry have; innovative technologies in the industry; distribution of products (dealership network); financial resources; the quality of customer services.

In contrast D. Cravens's approaches to the category of competitiveness of the industry and its enterprises was abstract as he identifies it as key competitiveness factors such key competitive advantages as flexibility (competitive advantage in different situations) and the complexity of technologies duplication developed in the industry.

Table 2.1 The Evolution of the organization's competitiveness management concepts

No.	Concept	Year	Authors (country)	Content of the concept
1.	The concept of integrated quality management	1951	A. Feigenbaum. E. Deming (USA)	The competitiveness and efficiency of the company's operation depend on the quality of the products produced. Therefore, in order to ensure the quality of the product, the technological production process is to be broken up in such a way as instead of confirming the quality of the final product, ensure it at the level of the main functional units and processes with direct participation and the corresponding level of professional and technical training and responsibility of direct executors
2.	The concept of knowledge management and organizational learning	1966	P. Drucker, P. Senge (USA)	The main changes in society occur with the development of information; knowledge becomes a central and key source that does not have a geographical location
3.	The concept of organizational culture	1970	E. Schein (Switzerland). W. Ouchi (USA)	Organizational culture is a set of rules, instructions, norms and principles of personnel behavior that help form a united team, competitive positions of the company in the market and adapt to changes in the external environment
4.	The resource-based concept	1984	B. Wernerfelt (Denmark), D. Collis, S. Montgomery (USA)	The company's resources include physical (real estate, raw materials, etc.) and intangible (know-how, reputation, patents, etc.) assets, as well as organizational capabilities that may be, in one way or another, the sources of competitive advantage
5.	The concept of business process reengineering	1990	M. Hammer, J. Ciampi (USA)	In an age of post-industrial society, corporations form, develop and increase their competitive advantages not on the basis of the specialization of labor, but on the basis of the reintegrating separate operations into unified business processes
6.	The concept of dynamic capabilities	1997	D. J. Teece (Great Britain)	The company's capability is in its dynamic adaptation of manufacturing to a rapidly changing environment and restructuring its competences with the aim to achieve new innovative competitive advantages

Source: Compiled by the authors

The analysis of literature on competitiveness management demonstrates that the concept of competitiveness came into being relatively recently. The scholars' works to a greater or lesser degree reflect the global market and open competition realities, practically ignoring the mechanisms of public support.

According to R. A. Fatkhutdinov, competitiveness characterizes the organization's ability to compete with its rivals and the ability to produce competitive products for sale in the domestic or foreign market. The author notes that competitiveness of the organization's personnel ensures the competitiveness of technical, technological, social and economic systems. Eventually, the higher the competitiveness of goods and services, the higher the competitiveness of the country, the efficiency of the resources use and the living standards of the population.

Shaping his approach to the definition of competitiveness, G. Kulikov distinguishes between real and nominal competitiveness. The real competitiveness of the country, in his opinion, is the ability of the economy to produce goods and services in a free and fair market that meets the needs in both domestic and foreign markets. Nominal competitiveness is achieved by pursuing a certain public policy that shapes the macroeconomic environment through direct government subsidies for national producers.

Based on the analysis and generalization in the works by these authors, relying on practical experience in the competitiveness management in high-tech industries, A. A. Chursin formulated the law of competitiveness management, the key idea of which is that increasing competitiveness is the first step to the growth of financial and economic indicators. A number of postulates derive from this law, which can be used in practical solutions to managerial problems. For example, the need for intensive management of competitiveness during the periods of depression and economic stagnation is mathematically justified to ensure the increase in production and products marketing. The law highlights the importance of launching hi-tech products with high added value.

First of all, it is necessary to single out and analyze the concept of competitiveness in its application to large innovation-active enterprises in strategically important industries. Competitiveness in this regard has a number of features associated primarily with a longer evaluating and planning the horizon for these enterprises, based both on the objective length of the relevant research and production cycles, and on the possibility of obtaining public support.

Obviously, for any business competitiveness is a dynamically estimated category, which is probably has strategic characteristics. Enterprise competitiveness is by no means identical to the competitiveness of its current product line, although it is closely related to it. The competitiveness of products in the short term depends on both the market conditions and the availability of financial opportunities to increase it through a variety of direct and indirect methods of subsidizing sales.

However, in the long term, such artificially maintained competitiveness can result in depletion of resources and corresponding negative consequences. In the long run, the competitiveness of products can be based only on the enterprise capability to offer products in demand in the market on conditions that support the process of expanded reproduction and scientific and technological development. Accordingly, the right balance between these enterprise capabilities and its rivals defines its strategic competitiveness.

With regard to strategically important innovation-active industries, it should be emphasized that the duration of the "first phase" (products competitiveness achieved through its artificial subsidies) can be significantly longer than in most consumer goods markets, since the importance of products in such industries for public allows significantly increasing the time and scale of its explicit or implicit subsidizing by the government in order to achieve subsequent long-term benefits. For example, the diversified technological empire of Elon Musk is fueled by government subsidies totaling approximately $5 billion and successfully continues its activities, despite losses in virtually all areas of its business. However, in the future such large-scale projects, which have reached technological and market maturity, make it possible to implement so-called "blue ocean strategy", i.e. long-term dominance in the new product market.

It should be noted that in many consumer goods markets, the situation is just the opposite: the market is dominated by the competitiveness of the products supply. If new marketing or technological ideas emerged in the market the product as a rule may be produced with the use of extensive cooperation (outsourcing, outstaffing, contract manufacturing, teleworking etc.), and immediately after the demand for the product stops being so pressing the production alliance can be disbanded and its components can be reconfigured for other product manufacturing.

Taking into account the fact that modern scientific research, R&D, processes of development and introduction of new manufacturing technologies are becoming increasingly expensive, which makes their maximum universalized application a vital need in all possible market niches; the urgent goal becomes, on the one hand, the fusion of both approaches to competitiveness of the strategic core of the company in accordance with long-term interests even through cross-subsidies within the corporation or targeted mechanisms of state support, on the other hand, the production in the framework of ad hoc alliances.

The importance of innovative component in the process of building up competitiveness is mentioned in the works by a number of scholars (A. P. Bunich, Yu. N. Makarov, N. A. Okatyev etc.) Most researchers note that the competitiveness of a modern organization is directly dependent on the introduction of novel technologies, the manufacturing of innovative products and the improvement of economic mechanisms and business governance instruments. At the same time innovations does not appear in a vacuum, a way should be paved to achieve the active innovation growth. It is necessary to develop complex factors of the innovative capabilities of the enterprise: financial and economic, R&D, production and technological, personnel, organizational, managerial, marketing and information-methodological.

At the present time, human and research factors are becoming increasingly important for innovative development and building up the competitiveness on its basis: they both are related to the fundamental processes in the modern enterprise—knowledge management.

The organization retains its competitive advantages in the long term only if it relies on rare and unique resources that are beyond competition. These resources constitute the uniqueness of the organization as a scientific and manufacturing system.

The main resource of science-based business is its employees' knowledge and experience, in other words, their ability to tackle certain problems. Since recently, to name such knowledge and skills the term "competence" have been used.

In the past the terms "competence" and "competency" were considered rather narrow and ambiguous. In jurisprudence, they meant a set of rights and powers of the authorities, in the field of psychology and pedagogy they meant the totality of knowledge, skills, abilities and proficiencies of an individual person. However, in the middle of twentieth century American economist P. Selznick applied this concept to the organization, extending it to the totality of knowledge, skills and abilities of a certain group of people. Later, the idea was developed in the research of other scholars, that resulted in the emergence of a new branch in the organization management, in which the resources and capabilities of the organization were viewed as the basis for gaining competitive advantages. As a matter of fact, competencies supplemented and developed the existing resource view on management. "Resources are the whole set of assets, capabilities, organizational processes, brand attributes, information, knowledge, etc., under the controlled of the enterprise that allow it to develop and apply strategies leading to improved rationality and production efficiency."

But for the company not only the resources themselves important are important, but also the possibilities of their rational use. That is why the notion of "resources" and "abilities" came to being: a company can extract rent not because it has larger resources, but because it has a distinctive ability to better use these resources.

The organization resources were interpreted widely, defined as "capabilities". The resources are described as an application area of competencies, and competencies—as a potential use of resources.

Capabilities or competencies are a pivotal concept of the resource approach. These are regularly repeated, predictable (standard) ways of business behavior of the whole organization or individual. It is the standard of these actions that ensures the retention of specific organizational knowledge. The standard is the result of the organizational learning process. Performing standard operations allows the company to accumulate implicit knowledge that is inaccessible to its competitors and achieve uniqueness in the use of company resources. Thus, organizational capabilities are determined by organizational nature, they do not depend on a single individual and are usually located within the functional divisions of the company. Accordingly, they cannot be easily bought or sold.

This study reflects the majority of scholars' view on the interchangeability of the concepts of "capabilities" and "competencies". The difference lies exceptionally in the importance of a particular capability for the company.

For example, John van Maurik defines competency as "the result of collective efforts and learning in an organization that meets the following requirements: providing access to a wide range of markets, bringing significant benefits to customers, difficult to simulate." D. Campbell, J. Stonehouse and B. Houston describe competencies as a property or a series of organization-specific properties that allow manufacturing goods of a higher quality than the average accepted in a particular industry. As J. Kay thinks that competencies are combinations of available resources and internal potential of an organization that are unique to a particular company and are the basis for shaping its competitive advantage by creating a unique value that is evaluated by the client.

C. K. Prahalad and G. Hamel understood company's competency as capability that the organization implements exceptionally well, or the capability that is crucial for the company's performance. The term "core competences" was used to highlight this particularly important competence. It involves the ability to produce something that other companies cannot produce at all or of a much poorer quality. To other, minor achievements, the term "competences" are not applied, but the notion of "sufficient competences", "core competencies" and other terms are used that underline their lesser importance for competitiveness.

Thus, there are several opinions about the reasons for the success of companies. M. Porter traced the sources of sustainable competitive advantages of a company in value chains. In his opinion, the advantages in competition cannot be understood if you look at the company as a whole. The actual advantages provide the opportunity to minimize costs, that is why the differentiation should be found in the chain of actions that the firm is carry out to deliver certain value to its customers. In M. Porter's opinion, the source of advantage to some extend is located outside the organization and predetermined by the sphere of its operations. For manufacturing companies, the key competency always lies in the use of advanced technologies, for trade—in logistics, etc.

C. K. Prahalad and G. Hamel, in turn, sees success in a combination of internal factors, in key, basic competencies, i.e., skills, abilities and technologies that allow the company to provide goods to consumers rather than in a combination of external factors affecting enterprises.

This raises the question of the difference between competencies as in a certain way organized by the intelligent potential of the company and intelligent resources as a part of its resource system. We consider that the distinction should be drawn on the basis of self-reproducibility criterion. The superiority in intelligent resources required for gaining competitiveness can be static (availability of necessary know-how, patents related to human capital, etc.) at a given time and dynamic (for example, the capability to attract highly qualified human capital owing to the proximity to the university center); but at the same time this priority can depend on external factors. If, however, the company manages to streamline knowledge in the field of producing in a special way intelligence capital, which allows guaranteeing its accelerated production in comparison with competitors, such organized knowledge can already be considered a special competence.

In accordance with this distinction, a strategic competitive position can be based on resources or competencies. The advantage in resources in the modern world can be lasting only if it relies on the unique resources (in absolute terms or by the ratio of price and quality, for example, the abundance or cheap resources). For high-tech innovation-active enterprises resources are not usually crucial, but the existing production capacities, intellectual and human capital are more important. At the same time, the possibility of achieving a sustainable, long-term competitive strategic advantage based only on the advantages in the availability of these resources, is questionable, since in the modern world intelligence and human capital is very mobile, and the importance of unique production resources decreases as universal manufacturing structures spread (at the macro level—the so-called contract manufacturers, whose operations relieve the vast majority of companies from necessity to maintain their own production, is particularly visible in microelectronics; at the micro level—the universal industrial technologies, including the 3D printing). Accordingly, the importance of competencies is growing in the ensuring a long-term competitive advantage. Competencies as in special way organized knowledge will allow the firm to organize a self-reproducing process of improving competences and increasing the efficiency in the use of resources. If it is too hard for rivals to reproduce a competence, it can be called a core competence.

The division of competences into core and other competencies is conditional and depends on specific circumstances, market conditions and other factors. The competence which is recognized today as a core one, tomorrow can become basic, and conversely, an unimportant competence, and those which are now peripheral can be of decisive importance in the development of the company largely due to the unpredictability of innovative processes. The enterprise must have information about the maximum number of its competencies, while retaining the opportunity to promptly reshape the development priorities, flexibly adjusting to market requirements. In this case, the concept of competence is regarded broadly including all knowledge, skills, abilities and capabilities of a person or a group of people that enable them to perform their high-quality work, among other things using the appropriate equipment and tools aimed at developing, producing, operating and marketing globally competitive products and providing certain types of services.

In the information-oriented society and fast-paced market the competence of the organization is fast-moving, when knowledge from unique can quickly become ordinary if it is not constantly being improved. The maintenance of the competence under such conditions, not only requires certain knowledge, but also dynamic organizational capabilities for rapid adjusting and updating knowledge through a system of continuous training, development of cooperation, etc. This will allow constantly developing the base of organizational knowledge and maintain it at a level not lower than the main competitors have.

According to D. Teece's concept, the company is the depository of knowledge that is embedded in the business processes of the organization. This knowledge base includes technological skills, knowledge of customers' needs and suppliers' capabilities. The set of technological and managerial competences reflects individual skills along with distinctive methods of doing business within the company. The essence of company's efficient activity lies precisely in its ability to create, transfer, consolidate, integrate and operate knowledge as assets. D. Teece defines this feature is "dynamic capabilities". He thinks that there are four dynamic capabilities of the company:

1. Competence of transaction management;
2. Business intuition;
3. Availability of typical innovation and changes management processes;
4. Mechanisms of making accurate decisions.

The works by I. A. Khanykov, D. V. Gorbunov and V. O. Sokolov deal with the issues of business development and organization's competences management, define the approaches and develop the methods of distinguishing and ranking these competences with the use of expert assessment.

The research by A. L. Nosov investigates the problem of efficient competence management. In his opinion the competences efficiency depends on the factors outside the company science they additionally influence the organization performance and, consequently, competence cost advantage. The level of competence that are not efficient under one conditions, can be quite efficient under another and vice versa. Therefore, the assessment of the efficiency should be made constantly and become an element of a feedback in the process of competences management.

We should note that the scholars' papers still have not demonstrated the influence of core competency on the innovative development of the organization. This issue needs to be seriously addressed.

There is one more view on the development of competencies related to the possibility of using them to compensate for risks and increase in competitiveness in innovation, which requires detailed study. An analysis of the risks of innovation was carried out by such researchers as A. T. Karzhaev, E. E. Kulikova, S. Filin, A. N. Folomiev et al., whose works the problems of the organization's assessment and management of risks arising in the process of implementing innovative projects were studied. However, the listed authors did not deal with the problem of assessing and compensating for various kinds of risks arising in the management of the key innovative competencies of the corporation.

To date, the crucial condition for the development of a company is not only a certain mass of knowledge, but also the ability to connect this knowledge with resources, processes, goals and objectives needed to maintain long-term competitive advantages. A fundamental difference between the theory of competence and traditional approaches to knowledge management is the close interrelationship of a formalized set of knowledge in the form of intellectual property assets (technologies, know-how, patents, etc.) with the unformalized abilities of their creation and use. The competitive advantages are connected both with the command of knowledge, and with ability to apply this knowledge with the aim of the activity diversification.

The capability to use knowledge becomes a primary factor in increasing competitiveness. A new paradigm arises: the value is not the asset itself, but the actual, based on the competencies of the organization's employees, the possibility of using it in the core and related areas. With regard to knowledge-intensive organizations this implies changing the methodologies for assessing their activities and potential opportunities.

The development of a new course of knowledge management through a competence approach allows the wider use of the scientific and production potential of enterprises and reflects the advanced trends in management. The task of competitiveness management is of practical importance as a management tool and needs the most adequate models that would take into account macroeconomic, sectoral and internal microeconomic factors of competitiveness.

Close correlation of employees' individual abilities with the company's competitiveness is directly reflected in all basic works on quality management (W. Deming, P. Crosby, W. Shewhart, K. Ishikawa and others). Today it can be argued that the competency factor should take its place among the proactive factors of the organization's competitiveness management along with the traditional criteria of innovation potential assessing, since the use of the most advanced equipment and continuous innovation development without competent specialists in the long term is not just impossible.

The described approaches to competitiveness management are interesting in the framework of studying the role of competencies in the process of acquiring and developing the organization's competitive advantages. Nevertheless, the analysis of the theoretical fundamentals of competitiveness management at the microeconomic level shows that in the examined papers there is no approach to managing complex integrated structures that are being created or have already been created in high-tech industries.

In that context given the absence of well-developed theoretical and practical aspects of competitiveness management of high-tech corporations and the urgency of this issue for many countries in the world, it is necessary to develop methodological tools for building competitive advantages and managing them, a holistic competitiveness management system, on the basis of core competencies at various levels of management—from products of a separate company to the corporation or industry. In this case, it is possible to witness a multiplier effect throughout the organization (usually this refers to improving management tools, the employees' skills, introducing new basic technologies, etc.).

The US Department of Labor (DOL) developed a nine-level Advanced Manufacturing Competency Model (AMCM), where competence was defined as follows: a cluster of related to it knowledge, skills and capabilities that affect most of the work (role or responsibility), which correlates with its official duties, and which can be measured in compliance with the accepted standards and improved through training and development.

The competency model is a set of competencies that ensure successful work in a specific situation. Competency models form the basis for important human resource functions, such as recruitment, training, development and performance management. Competency models can be developed for a specific job, group of workers, organization, profession or industry.

The competency model comprises:

– The competency name and its description;
– The description of an activity or behavior;
– The model diagram.

The DOL model is depicted as 9-tier (or 9-level) pyramid. Levels 1–4 are a set of qualification areas represented in the pyramid as blocks. The competency elements for each of these four levels include a list of knowledge, skills and capabilities that are considered necessary for successful work in manufacturing.

Levels 1–3 are fundamental competencies that are applied in all manufacturing industries. They consist of:

- The competency of an individual efficiency.
- Academic (educational) competencies;
- Job competencies.

Level 4 is an industry-wide technical competencies—includes cross-cutting industry-wide competencies required at different sectors of manufacturing. The model provides greater detail (such as critical work functions and technical content areas for both entry-level and practitioner-level technicians) for competency areas. DOL data is presented only at levels 1–4, while the remaining levels (5–9) are intended for the competency of a specific industry sectors.

In our case, core competencies for the aerospace and defense industry (ADMCM) have been identified. This competency model describes a unified interface of production, science and technology, research, design, development, production and self-sufficiency, corresponding to the structure of the level of manufacturing readiness (MRL). The model also supports an environment in which productivity, manufacturability, design, risk management, and quality control systems are fully integrated.

The ADMCM model identifies the levels, sectors competencies as well as the competencies required to fill the tiers 5–9 of the DOL model.

The aerospace industry competency model also contains data not included in levels 1–4 of the DOL model:

- Level 2—academic competencies, includes the field of engineering and technology competencies;
- Level 3—job competency, includes the area of innovations competencies;
- Level 4—sectoral technical competencies, includes three areas of competence; the fundamentals of the aerospace industry, its design, development and maintenance. Three qualification areas of this level—components and products manufacturing, project management, and ensuring the quality and safety of the environment and health—have analogy at level 7;
- Level 5—technical competencies of aerospace and defence industry;
- Level 6—the competency of the facilities and equipment development;
- Level 7—the competency of planning and maintaining;
- Level 8—the competencies in the field of contracting;
- Level 9—competency of risk management.

Thus, we see that this competency model for the aerospace industry contains all necessary competencies, as this paper says. In addition, it is associated with the structure of the manufacturing readiness level (MRL), on the basis of which the process of production in the aerospace machinery is carried out.

Key competencies of enterprises and corporations are innovative combinations of knowledge, special skills, technologies, information and unique methods of operation that create products or services of value to consumers (clients). Organizations have many opportunities and competencies, but only a few are joined and integrated in such a way that they can be considered as a core. Competitiveness of enterprises and corporations based on core competencies makes sense only in markets where they compete for consumers, profits and market share with their products and services that meet customers' needs. Therefore, the list of core competencies of small enterprises contains 3–4 points, while large and global corporations—15–20. For example, the Airbus Group defines its core competencies in order to implement a product and service development strategy, in so doing the list of core competencies is constantly evolving and changing in accordance with the strategy. For example, in 2014, they made a list of 19 core competencies that were present at the level of the Airbus Group and its divisions ranging from engineering systems, quality and program management at the group level to more specific skills, including marketing and maintaining the aging aircraft fleet. These approaches can be witnessed in other large corporations of aerospace industry—Lockheed Martin Corp., Nortrop-Grumman Corp etc.

The "bridge" between the center of core competency and strategies is the concept of business model of an enterprise or corporate linking an internal assessment of organizational capabilities and strategic positioning in emerging markets. The core competencies of enterprises or corporations refer to their fundamental capability to carry out specific activities in creating values for the end user or to present these values more efficiently than other manufacturers. Accordingly, the business model can be characterized as an element of strategy and a tool of managing competitiveness. In the first case, all elements of the following chain of relationships are consistently articulated: key competencies—the business model of the corporation—the corporation's strategy. In the second case, four aspects can be distinguished: time of entry into market, technological and financial risks, interdependency among actors and expected return.

To develop these methodological tools based on the results of research conducted in the field of competitiveness management, it is necessary to analyze existing approaches to the increase in competitiveness of enterprises in high-tech industries.

2.2 Enhancing Competitiveness Tools for High-Tech Corporations Through Core Competencies Management

The analysis of theoretical approaches to competitiveness management demonstrated that foreign scholars have made further progress in studying this issue; they believe that a special role in these processes is played by the competency management, which comprises knowledge management, new technology development and the ability to use them.

It is not possible to improve high-tech corporations' competitiveness without managing core competencies that integrates the staff development (human capital), scientific and technical base and financial resources. One of the most important external factors determining the environment, in which the core competencies are shaped, is Knowledge Economy Index (KEI). This factor is extremely important for high-tech manufacturing.

The analysis of KEI rankings for countries in the world (Table 2.2) shows that the developed countries possess with the highest scores (Sweden, Finland, Denmark, etc.) and newly industrializing countries of Southeast Asia (Taiwan, Hong Kong). The Index is calculated on the basis of "Knowledge Assessment Methodology" designed by the World Bank.

The group of leading countries in global knowledge economy and knowledge indices listed in Table 2.2 left behind other countries in the field of scientific and technological development. This is due to the fact that the business entities of these countries, having the above-mentioned key factors of competitiveness, are able to manage it skillfully.

There are a number of other countries with a poorer resource base that thanks to the implementation of modern tools in managing competitiveness, knowledge and competencies succeeded in taking their scientific and technological development to a qualitatively new level.

This is confirmed both by R&D of these countries and high-tech products manufactured by their companies, as well as by their high positions in the international subscripts (Table 2.3).

Consider the instruments of competitiveness management based on the mechanisms of knowledge and competencies management, the application of which provides the above-mentioned countries with a high position in the world ratings. These instruments can be combined into several groups based on the types of organization.

Institutional sphere

1. Establishing the centers of open innovations
   One of the most effective mechanisms used in innovation and competency management is the establishing of open innovation centers in the form of minor organizational units that accumulate information about the competencies available in the organization. As a rule, the employees of these centers are divided into two groups: specialists involved in information base administrating and experts in a subject area who consult the organization's subdivisions on required information retrieval.

   Nowadays, the open information centers are becoming one of the pivotal structures in the process of strategic management in ideas and intellectual resources exchange between organizations with the goal of joint value-adding. For example, the Garwood Center for Corporate Innovation, an open innovation center, has been established in the USA and now successfully operates in the country. Its activities focus on accumulating large corporate innovations,

Table 2.2 List of top knowledge economy index rankings by countries (2013–2015)

Rating position	Country	Knowledge economy index	Knowledge index	Rating position	Country	Knowledge economy index	Knowledge index
1	Sweden	9.43	9.38	11	Ireland	8.86	8.73
2	Finland	9.33	9.22	12	USA	8.77	8.89
3	Denmark	9.16	9.00	13	Taiwan	8.77	9.10
4	Netherlands	9.11	9.22	14	Great Brittan	8.76	8.61
5	Norway	9.11	8.99	15	Belgium	8.71	8.68
6	New Zealand	8.97	8.93	16	Iceland	8.62	8.54
7	Canada	8.92	8.72	17	Austria	8.61	8.39
8	Germany	8.90	8.83	18	Hong Kong	8.52	8.17
9	Australia	8.88	8.98		…		
10	Switzerland	8.87	8.65	55	Russia	5.78	6.96

Source: Compiled on the basis of information-analytical portal "Center of Humanitarian Technologies". URL: http://gtmarket.ru/ratings (date of address: 3/18/2015)

Table 2.3 Knowledge economy subscripts for nations of the world (2013–2015)

Country	Education index (2013)		Innovation index (2015)		ITC index (2015)	
	Rating	Indicator	Rating	Indicator	Rating	Indicator
Sweden	19	0.844	3	62.40	5	8.67
Finland	23	0.815	6	59.97	12	8.36
Denmark	9	0.873	10	57.70	2	8.88
USA	5	0.890	5	60.10	15	8.19
Hong Kong	42	0.767	11	57.23	9	8.52
Russia	36	0.780	48	39.32	45	6.91

Source: Compiled on the basis of information-analytical portal "Center of Humanitarian Technologies". URL: http://gtmarket.ru/ratings (date of address: 3/18/2015)

introducing and developing new business models to reflect the value of innovative products and services, as well as providing educational services to company management involved in innovative activities.

Russia also actively practices the establishing of centers for open innovation, for example, the State Rostec Corporation set up such centers on the basis of two universities: Plekhanov State University and Peoples' Friendship University of Russian. However, these centers embrace the activities of all high-tech industries, while due to the rapid development of the global space industry, an increase in the number of countries operating in this field, and greater number of companies within the space industry of one country, highly specialized centers and platforms for open innovation are being organized abroad. So, NASA has established an innovative pavilion (center) based on the InnoCentive open innovation platform, which to date is dealing with the challenges of the US space industry.

The Japan Aerospace Exploration Agency has founded the Center for Open Innovation with the activities aimed at combining scientific research and innovative solutions in the field of mankind survival and supporting human life and activity on our planet. As a result, the Japan Aerospace Exploration Agency has formed a new system for managing intellectual property and personnel competencies that enables any Japanese aerospace company to share knowledge that promotes solving a specific problem.

In general, the establishment and operation of open innovation centers contributes to decreasing resources required to manufacture innovative products for the technology buyer thanks to acquiring technological solutions available on the market and increasing the seller's profit through the utilizing existing competencies, which eventually can lead to increased competitiveness of both parties.

2. Public-private partnership

   In order to ensure the innovation implementation, which is a generator of innovative competencies, and therefore, a prerequisite for increasing competitiveness, the government applies various measures of support. An important aspect of such measures is the need to combine public and private resources that will not only increase the overall resource capacity of support, but also effectively combine the advantages of public strategic goal-setting and private control over the effectiveness of individual business operations.

Therefore, it is expedient to provide the support for innovation in resource-intensive and strategically important sectors on the basis of the public-private partnership development. In the United States there are cases of successfully implemented projects within the public-private partnership of the Defense Advanced Research Projects Agency (DARPA) with a number of industrial companies:

– The development of the Aquarius launch vehicle for launching small, inexpensive payloads (PL) of light weight (up to 1000 kg) to low-Earth orbit (partners: Space Systems/Loral and DARPA); in 2004, $1 million was allocated to the project from the DARPA budget;
– The development of LV Falcon SLV (Space Launch Vehicle) for launching both from stationary and mobile launch facilities designed both for civil and, primarily, military application (partners: Lockheed Martin and DARPA);
– The development of SLC-1 LV for launching commercial LV weighing less than 150 kg to low-Earth orbits (partners: Space Launch Corp. and DARPA). Along with the implementation of the commercial program, SLC, together with DARPA, participates in the RASCAL program (Responsive Access, Small Cargo, Affordable Launch) aimed at ensuring that a reconnaissance micro-SC is deployed within a few hours in order to detect a security threat in time.

Organizational support in the field of public-private partnership and stimulation of the joint projects implementation can be based on the involvement of innovative intermediaries in innovation processes [one of the most important elements of the innovation infrastructure at the micro level (innovative agencies, venture funds, innovation centers based on universities, etc.)], whose tasks include the development or assistance in the development of innovative competencies, as well as the development of business plans based on available innovative technology. Sectoral intermediary organizations are widely used in foreign countries. So the innovative system of the US aerospace industry is represented by a number of federal, public and private intermediary structures. For example, there is a special Center of Excellence in commercial space transportation area under the Federal Aviation Administration (FAA)—COE CST, which is a virtual community of professionals in the field of commercial space activities, whose activity is designed to achieve a specific, for example, business results. Practical interaction with participants of this intermediary organization allows evaluating the competency of a particular participant and building long-term relationships with them.

Personnel management and specialists training sphere

1. Personnel planning.

   Personnel planning is one of the most important functions of organization personnel and employees' competencies management; it is especially important for a strategy of its development, since accurate records of future needs allows the organization to make precise plans, organize reserve labor pool and develop employees' competencies.

The competencies development ensures greater competitiveness, which, first of all, is based on the planning of human resources. In order to develop the competencies of their employees, high-tech corporations in foreign countries found corporate academies, send their employees abroad for trainee jobs to expand knowledge in various fields and lay the groundwork for generating new ideas using modern IT technologies, conduct distance training, web seminars, teleconferences, in which leading foreign scientists and practitioners can take part sharing their knowledge. Following the intensive development of information technologies, the new forms of personnel training have emerged that allow the organization to run distance courses and carry out further training for students on educational programs. These forms are audio and video conferences, webinars, on-line discussions on the basis of Internet forums, etc.

2. Forming Project Teams

   At most enterprises, each department has its own functions, and its organizational structure is constant. However, for solving new problems in manufacturing a unique innovative product, there is a need for joint work of multidisciplinary specialists with the necessary set of competencies. Such problems can be solved through launching projects and forming a project teams.

   If for implementing the project more than 1 year is required, abroad an independent division is usually established within enterprises: a working group that becomes a separate structural unit. The project manager—who is the head of this division as well—is entrusted with the same authority as other top managers of the enterprise. For example, a similar division employing two hundred people was established in "Daimler-Chrysler" with the aim to develop a new "Mercedes" model. The working group members were fully involved in one project and were not engaged in other activities.

   The forming of project teams enables the organization to concentrate the knowledge and competencies of its employees on the development and manufacturing of one unique innovative product, which can potentially provide the manufacturing company with competitive leadership in both the domestic and foreign markets.

Scientific and technological sphere

1. The development of corporate science

   High rates of innovative development and competitiveness increase are demonstrated by the countries, which successfully conduct corporate scientific research. The connection between the real sector, science and education can produce a high synergetic effect with due support from the government. For example, according to the report of Lux Research, the US retained its leadership over all other countries in terms of public funding, which amounted to 1.67 billion dollars in 2014. In the EU countries—Denmark, Finland, Great Britain, France, Germany, Austria, Belgium, Czech Republic—the share of expenditures on corporate science in the total R&D costs is about 65%, and in the USA—approximately

70%. China spends about 71% to retain its leading positions, Japan and Israel—about 75%. Sweden, the leader among the EU countries, sends about 77% to support corporate research.

2. Outsourcing of scientific laboratories, institutes and educational establishments' services.

   Foreign experience shows the success of outsourcing of scientific laboratories, institutes and educational establishments' services. Such interaction allows companies to remain at the center of scientific and technical information flows and develop their own innovative capacities, lay the foundation for their competitiveness at present and in years to come. In the twentieth century the largest companies independently conducted scientific and technical research, but in the end came to understand the necessity of consolidating their efforts and work with universities and scientific centers. Nowadays in the situation of intense competition and high innovation risks the requirement for wide range of technologies necessary to innovate encourages the companies to shape new strategies. New strategies are built on the basis of creating a network model, which provides for the strengthening of the specialization of corporate scientific laboratories and the formation of innovative chains of interaction. Knowledge networks are created at the discretion of a company and its management. The company involves scientific institutes, universities, laboratories, state institutions, etc. into the innovation process. Open innovation ecosystems are being formed, that are aimed at creating new business opportunities by sharing the complementary knowledge and competencies of different partners, including not only suppliers, customers, and research organizations, but also competitors. It is important to say that this system of integration can be implemented at a global level. The analysis demonstrated that developed and developing countries choose the way of industrial specialization acting as the most important hubs of international production and scientific relations.

   Effective interaction with research institutes and universities can also play an important role in the formation of competencies and innovative development of the corporation. For example, Intel does not conduct research and develops technologies or products at its own research centers, but outsource it to universities or research institutes. Research centers and universities may propose several solutions. The goal of the contractor is to properly integrate into the chain of interaction with customers. The result of joint work is to be objects of intellectual property. Rights to intellectual property should belong to the developers—universities and research centers. For example, Intel reserves the non-exclusive right to use the developed technology in its production.

3. Technology transfer.

   When working on increasing the competitiveness of a product or business process, the main tool that links the developers of innovation (technology) and its recipient is technology transfer, the goal of which is the active introduction of innovations in the industry. Technology transfer is actively used to improve competitiveness abroad. For example, in Switzerland the transfer of innovative technologies takes place through technological parks and technology transfer centers. Sweden practises the method of creating a complete innovation chain (the union of technology transfer centers), allowing the project to be implemented from an idea to a small promising enterprise. Technology transfer in the United States is included in the universities' missions along with traditional scientific and educational activities. In China, in 1998, only a few universities had technology transfer structures, but today every university has a similar unit. Technology transfer centers operate as associated private companies. In Japan, national research universities are responsible for the transfer of technologies.

Information and communication sphere

1. The identification of market demand for products with certain innovative properties, created on the basis of unique competencies (in other words, the identification of market demand for the competencies).
   The identification of market demand for goods with certain innovative properties is impossible without information and communication activities, which is the key to a successful study of the market of high technology products and technologies. To determine the demand for competencies, foreign high-tech companies often use standard modern marketing tools: benchmarking, work with internal and external experts, including foresight, market testing, Customer Development, etc.
   The use of benchmarking is determined by the increased dynamism of the external and internal environment at companies in an unstable market economy. It is one of the innovative approaches to improving all aspects of business, focused on the continuous increase in its competitiveness, on the basis of identifying areas for the development of new competencies. The concept of benchmarking is used as an auxiliary tool for gathering information and identifying the competencies needed for the organization to continually improve productivity, quality and competitiveness.
   The development and deepening of each management function, as well as the formation of new competencies, occurs not only under the influence of internal regularities, but also under the influence of the requirements for the development of other functions. In this situation, the ideology of identifying the direction of new competencies development is foresight, i.e. a method of identifying directions for the development of the company and new competencies, which is based on the methodology of the process organizing, aimed at creating a common vision of the future for the participants.
   The concept of Market testing and Customer Development are used in cases when, in order to increase competitiveness, along with research and data collection to understand the directions for the formation of new competencies market testing (test marketing) is required that allows testing products and marketing program under real market conditions. The testing is aimed at forming competencies related to the marketing approach to the analysis of innovative projects at various stages of developing a new product and plans for its promotion in the market in order to enhance the company's competitiveness.
2. The formation of competency centers.

With regard to competency management, information and communication technologies (ICT) are used in such an effective mechanism for receiving feedback from the labor market about supplying staff competencies and promptly responding to the companies' requests for finding relevant competencies, as the competency centers (exchanges of competencies) that represent the database that gather and store the information about those who can solve problems or possess knowledge important to the profile of companies. These centers store requests for competencies and an "innovation order" from subdivisions and other participants in the site. Competency center is an external source of competencies on the basis of outsourcing. InnoCentive project is an example of the on-line center completely developed into the "knowledge and technology market". Consolidating in one place, in one customers team, who need to research any objects, applied scientific problems, the best researchers, a group of inventors and scientific specialists is able to give better results. Competitive conditions of involving research teams from different countries of the world into scientific research will allow inviting the best specialists for solving specific scientific problems.

The effectiveness of the used instruments, in our opinion, depends on many factors, the main of which are: the possibility of their adaptation in accordance with the current system of state regulation of economic activity of high-tech enterprises and integrated structures; the availability of a certain range of competencies among the employees of the organization responsible for the implementation of these tools and mechanisms; the availability of specific practical recommendations, techniques, and instructions that can be readily implemented in the enterprise.

In this regard, it is required, firstly, to analyze the development of a particular high-tech industry; secondly, to identify the ways of solving them with the use of tools for improving competitiveness; thirdly, develop sectoral methodological tools that allow assessing and ranking key competencies of a high-tech corporation, and build models for assessing their impact on innovative development. It is necessary to create the sectoral tools that would take into account the competitiveness of products through the introduction of innovative technologies with the use of core competencies and would allow evaluating and improving the efficiency of the competency management process at high-tech corporations, risks in the formation of a system for managing core corporation's competencies, etc.

2.3 The Law of Interinfluence Between Core Competency Financing and the Rise of New Consumer Markets

The analysis of the common patterns that characterize the correlation of unique competencies with formation of new consumer markets showed that the process of their emergence is typical of formation of a national knowledge economy, the main elements of which are the competencies of corporations and innovative technologies.

Formation of intellectual economics is targeted at developing new products, services and rapid growth of new markets, which in turn generates the demand for higher level of competencies and introduction of innovative technologies. Thus, the economy witnesses a spiral trajectory of its development, which is explained by the law deduced by the authors from the relationship between the growth of competence level and the emergence of new markets. In its turn the law not only illustrates new economic patterns, but also is used as a postulate of a microeconomic theory describing specific features of the knowledge-based enterprises functioning.

The model "Competencies-innovations-markets"

The modern world economy is getting more and more oriented at a new economic type—knowledge-based economy. Today, the resources that determine the further trajectory of the national economy development are not natural wealth, productive capacities, or even labor resources, but the unique competencies of corporations and employees. They play a crucial role both at microeconomic and macroeconomic level.

The development of unique competencies produces a significant synergetic effect in the economy, which manifests itself not only in the industry but also in education, as the demand for the competencies and high level of training generates the supply of new educational services. In addition, the development of competencies and derived from them new technologies lays the groundwork for new consumer markets development. Competition in the field of high technologies and unique competencies has mechanisms different from traditional industries responding more quickly to competitors' activity, which motivate companies to change rapidly and effectively their behavior.

Look at the model of correlation between competencies development and consumer markets, the correlation between which leads to spiral trajectory sustaining innovative growth of the economy. Schematically, this is depicted in Fig. 2.1.

Thus, the effective functioning of knowledge-based enterprises shapes the demand for innovative products. Consequently the demand for key competencies arises in new industries. Naturally, the increasing demand encourages the growth and application of key competencies. All this contributes to the development of

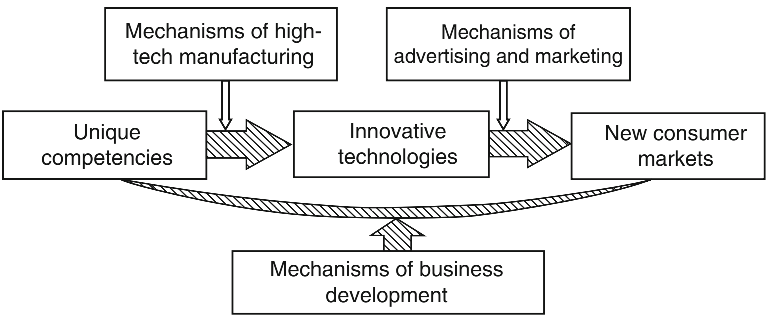

Fig. 2.1 Scheme of correlation between unique competencies and emergence of consumer markets

fundamental science, generates applied developments, and form the basis of innovative technologies, which are subsequently translated into the creation of new products or services. The aim of commercializing innovative technologies makes high technological companies create new markets and promote their new products there. As a result, these new consumer markets for innovative products trigger the rapid growth of the corresponding production, in which a large number of new core competencies are formed that in their turn result in emergence of new products and ultimately new consumer markets.

The model "Competence-Innovations-Markets" demonstrates that the higher level of competencies and encourages the widening of consumer markets at the expense of new products meeting new needs. In so doing the market mechanism causes the surge in investments into breakthrough technologies, which are used for these products manufacturing. According to the laws of innovative economics these innovations greatly extend competencies in this field. Undoubtedly, this surge takes place only for some time while consumer markets are growing impressively, but according to the economic law of marginal market saturation when they get saturated at some point of time, the growth sharply slows as the technologies that used to be innovative become ordinary. In the situation of the continued growth the economy needs the emergence of newer innovative technologies that become a prologue for further growth of consumer markets and, respectively competencies enhancement.

The provided example of the correlation between new competencies and new consumer markets can be described in the form of a closed economic model, which describes the internal processes of this correlation. This model can be represented in the form of the general law relating to the emergence of new markets on the basis of new key competencies depicting the spiral trajectory of "competences-resources-products-needs-competences".

In this work we suggest the hypothesis that as a result of the constantly recurring cycle of "growing markets—shrinking markets" a modern high-tech economy accumulates a sufficient stock of competencies, which in its turn forms the prerequisites for the emergence of a new cycle of markets and competencies growth.

Interpretation of the law through the mathematical model

The proposed model is described with some dynamic parameters that are interdependent and changeable as time goes on, namely:

- The level of technological competencies;
- The level of innovative technologies;
- The level of new products;
- The level of market development.

We use in the model the dimensionless numbers that is why not only particular values of a parameter are important but also their dynamics. Consider the details of the parameters listed above. The level of technological competencies describes the existing average level of technological competencies that can be used in high-tech industries to develop innovative technologies.

Another important parameter in the model is the level of innovative technologies; this parameter depends on the parameter describing the level of competencies. It characterizes the degree of innovative technologies introduction into the manufacturing processes. While calculating the dynamics of this parameter we should take into consideration the factors of the innovative technologies obsolescence when newer technologies replace the existing ones.

The parameter describing the level of new products is closely linked to the level of innovative technologies. The introduction of innovative technologies enables not only to improve the qualitative properties of the products or lower their costs but also provides the opportunity to design new products and services. Naturally, this level is a numerical indicator, which is used to specify the number of new products in the consumer markets. To calculate this parameter, you need to use econometric information, as well as comparative information about the indicators of products.

The most important parameter in our model is the one that represents the level of consumer markets. This level reflects the creation and development of new markets, emerging from the supply of new products. Accordingly, there is a positive feedback, which causes a further demand for innovative technologies, as well as the development of unique competencies.

For constructing the mathematical model of the law under discussion it is necessary to consider the formalizing of basic concepts. As we investigate the dynamic model we should introduce "time" into it. Typically, economic models include discrete time, since many processes develop over long time, but for qualitative results it is convenient to consider continuous time, since in this case more compact mathematical models are obtained.

$$t \in [0, T], \quad 0 < T < \infty$$

We consider the case of finite time interval. The characteristics of the mathematical model for describing the law on the correlation between competencies and new markets are the following variables:

C (t) a quantitative indicator of financing competencies;
T (t) a quantitative indicator of innovative technologies;
P (t) the quantitative indicator of products;
M (t) a quantitative indicator of new markets.

We consider the following system of differential equations:

$$\begin{cases} \dot{C}(t) = F_1(C(t), T(t), P(t), M(t)) \\ \dot{T}(t) = F_2(C(t), T(t), P(t), M(t)) \\ \dot{P}(t) = F_3(C(t), T(t), P(t), M(t)) \\ \dot{M}(t) = F_4(C(t), T(t), P(t), M(t)) \end{cases}.$$

The apparatus of differential equations used for formalizing the law on the competencies the interinfluence on consumer markets makes it possible to construct a qualitative mathematical model for investigating the dynamics of these quantities in different contexts.

When constructing formal bases for the model, we need to choose the basic numerical characteristics to describe the corresponding economic quantities, so we propose to consider dimensionless quantities that qualitatively describe the state of economic variables. Consequently, the numerical values of the functions C (t), T (t), P (t) and M (t) represent the values of integral indicators for describing the level of competence, the state of technology, products and consumer markets.

To obtain the qualitative description of mutual dynamics of competencies level and the growth of consumer markets, it is more convenient to consider differential equations. The case of continuous time can be replaced with a discrete one then in this case we can rewrite the differential equations used in the form of difference equations.

The dynamics of indicators before us to a first approximation can be described by means of a linear model:

$$\begin{cases} \dot{C}(t) = A_C C(t) + A_{MC} M(t) \\ \dot{T}(t) = A_T T(t) + A_{CT} C(t) \\ \dot{P}(t) = A_P P(t) + A_{TP} T(t) \\ \dot{M}(t) = A_M M(t) + A_{PM} P(t) \end{cases}.$$

In this model we consider a system of linear differential equations in which each dynamic variable has a certain diffusion coefficient that reflects an objective decline in every indicator over time, since without appropriate management indicators decrease due to the actions of competitors and the overall development of the economy and scientific and technical progress.

While modeling it is necessary to stress the fact that each subsequent indicator in it changes under the influence of the previous one, and the last indicator, the indicator of new markets, influences the initial indicator of the competencies level ensuring the cyclical economic development.

The main conditions of model formation are the following:

$$A_C < 0, A_T < 0, A_P < 0, A_M < 0.$$

This means that for every key indicator the model has time diffusion leading to a constant decline in the values of these indicators.

$$A_{MC} > 0, A_{CT} > 0, A_{TP} > 0, A_{PM} > 0.$$

This means that every key indicator is characterized by a positive dependence, which ensures their spiraling rise that reflects the main component of the law under consideration.

It is to be noted that the system of differential equations above do not take into consideration external impacts on the dynamics of indicators.

From this point on it is necessary to consider the following heterogeneous system of differential equations, which takes into account the external impact on the dynamics of integrated indicators:

$$\begin{cases} \dot{C}(t) = A_C C(t) + A_{MC} M(t) + F_C(t) \\ \dot{T}(t) = A_T T(t) + A_{CT} C(t) + F_T(t) \\ \dot{P}(t) = A_P P(t) + A_{TP} T(t) + F_P(t) \\ \dot{M}(t) = A_M M(t) + A_{PM} P(t) + F_M(t) \end{cases}.$$

Here, the functions on the right-hand side express an external effect on the dynamics of integral indicators. These functions can be deterministic if we consider a situation of purposeful management, and also they can contain stochastic components in case of considering random external influences on the dynamics of the considered indicators.

The proposed linear dynamic system for describing the interinfluence of the competencies level on the consumer markets development can only describe the period of increase in these values, therefore, to reflect cyclical phenomena when developing the level of competences and consumer markets we need to consider nonlinear dynamic models.

Nonlinear effects on the development of consumer markets are linked with the fundamental laws on every product marginal utility. The phenomenon of consumer markets saturation restricts the corresponding growth in competency indicators, as saturation of consumer markets reduces the operating profit of enterprises and limits additional investments in the production development and in the increasing of competencies level. In addition, the innovative technologies have their own saturation, which arises when the innovation capabilities of technologies are exhausted.

The analysis of literature revealed that cyclic phenomena have two distinct stages—growth and decline and can be described with the help of a nonlinear effect of hysteresis. In nonlinear dynamic systems the effect of hysteresis leads to the situation when the coefficients of equations change discontinuously if the values (solutions to the equation) reach critical levels. Let us describe the hysteresis function, which we use in our dynamic model to describe the cycles of development of consumer markets and the level of key competencies. For the dynamic variable Y (t), we introduce the following hysteresis function:

$$H[Y(t)] = \begin{cases} H_{\min}, Y(t) > T_{\max} \\ H_{\max}, Y(t) < T_{\min} \end{cases}.$$

We will consider four hysteresis functions HC, HT, HP, HM for the equation for competences, technologies, products and consumer market. Thus, to describe the law on correlation between competences level and consumer market we can use the following dynamic model:

$$\begin{cases} \dot{C}(t) = A_C C(t) + H_C[C(t)]A_{MC}M(t) + F_C(t) \\ \dot{T}(t) = A_T T(t) + H_T[T(t)]A_{CT}C(t) + F_T(t) \\ \dot{P}(t) = A_P P(t) + H_P[P(t)]A_{TP}T(t) + F_P(t) \\ \dot{M}(t) = A_M M(t) + H_M[M(t)]A_{PM}P(t) + F_M(t) \end{cases}.$$

As a result we obtain the model that is able to describe the cyclical dynamics of values "competences-technologies-products-markets".

The proposed model describes only the qualitative dynamics of the values concerning the relationship between the level of competencies and the expansion of consumer markets. For the quantitative analysis of specific situations, it is necessary to use accurate statistical data, with the help of which it will be possible to estimate the coefficients included into dynamic equations.

Thus we proposed the linear model of four interrelated indicators; under the general conditions the presented system has a trivial solution (equal zero). Determining the diffusion coefficients (diagonal elements of the matrix) by expressions. Within their meaning these coefficients should be negative; otherwise the process of changing the unknowns will have an increasing exponential nature. Absolute values of these coefficients should not exceed 1.

The values of the diffusion coefficients will have the form:

$$A_C := -1 \qquad A_T := -1 \qquad A_P := -1 \qquad A_M := -1.$$

The off-diagonal elements of the matrix describe the effect of the other indicators.

They can be arbitrary signs, depending on how any given coefficient affects other coefficients. However, their values should be sufficiently small, since it can be assumed that their influence is as big as the influence of the basic coefficient.

The values of deposit coefficients:

$$A_{MC} := 0.6 \qquad A_{CT} := 0.7 \qquad A_{TP} := 0.8 \qquad A_{PM} := 0.4.$$

For us the periodical and cyclical processes are the most important here. They can be realized only when the eigenvalues of the coefficients matrix are complex and their real parts are negative. For the above given values of the coefficients, the matrix of the system and its eigenvalues are equal.

$$A := \begin{pmatrix} A_C & 0 & 0 & A_{MC} \\ A_{CT} & A_T & 0 & 0 \\ 0 & A_{TP} & A_P & 0 \\ 0 & 0 & A_{PM} & A_M \end{pmatrix} \qquad Ev := \text{eigenvals}\ (A) = \begin{pmatrix} -1.605 \\ -1 + 0.605i \\ -1 - 0.605i \\ -0.395 \end{pmatrix}.$$

The larger the absolute values of the real parts of the eigenvalues, the faster the solution will tend to 0; this is actually what we can see. Thus, approximately in a time $|Re(Ev_0)| = 1.605$ the amplitude of the oscillations decreases by a factor of 2.7. At the same time, there is an oscillatory (cyclic) process with a frequency of $|Im(Ev_1)| = 0.605$.

Next we give an example of other values of the matrix elements of the system:

$$A_C := -0.9 \qquad A_T := -0.9 \qquad A_P := -0.9 \qquad A_M := -0.9$$
$$A_{MC} := 0.01 \qquad A_{CT} := 0.01 \qquad A_{TP} := 0.02 \qquad A_{PM} := 0.05,$$

$$A := \begin{pmatrix} A_C & 0 & 0 & A_{MC} \\ A_{CT} & A_T & 0 & 0 \\ 0 & A_{TP} & A_P & 0 \\ 0 & 0 & A_{PM} & A_M \end{pmatrix} \qquad Ev := \text{eigenvals}\ (A) = \begin{pmatrix} -0.918 \\ -0.9 + 0.018i \\ -0.9 - 0.018i \\ -0.882 \end{pmatrix}.$$

The attenuation reduced, and the oscillation frequency also decreased. Next we will be simulating with these values. Let us define the hysteresis function. The original model does not specify values that are possessed by the function in the range from T_{min} to T_{max}. Assume that this value is 2.

Hysteresis functions:

$$H_{min} := 0.1 \qquad H_{max} := 4 \qquad T_{min} := 1 \qquad T_{max} := 10$$
$$\text{Hist}(y) := \text{if}(y > T_{max}, H_{min}, \text{if}(y < T_{min}, H_{max}, 2))$$
$$H_C(y) := \text{Hist}(y) \quad H_T(y) := \text{Hist}(y) \quad H_P(y) := \text{Hist}(y) \quad H_M(y) := \text{Hist}(y)$$

We now proceed to solving the Cauchy problem for a system of differential equations. The system matrix, including both nonlinear terms and random elements, a normally distributed random variable with a mathematical expectation 1 and a standard deviation 0.9.

$$D(t,\ Y) := \begin{pmatrix} A_C \cdot Y_0 + H_C(Y_0) \cdot A_{MC} \cdot Y_3 \\ A_T \cdot Y_1 + H_T(Y_1) \cdot A_{CT} \cdot Y_0 \\ A_P \cdot Y_2 + H_P(Y_2) \cdot A_{TP} \cdot Y_1 \\ A_M \cdot Y_3 + H_M(Y_3) \cdot A_{PM} \cdot Y_2 \end{pmatrix} + 1\ \text{rnorm}(4,\ 1,\ 0.9)$$

Initial data:

$$Y0 := \begin{pmatrix} 1 \\ 1 \\ 1 \\ 1 \end{pmatrix}.$$

Define the parameters of the solution: the starting time $T_0 = 0$, the ending time $T_1 = 400$, the number of passing points $n = 1000$.

$$S := \text{rkfixed}(Y0,\ T0,\ T1,\ n,\ D).$$

We have selected the variables for constructing the diagram:

$$t := S^{\langle 0 \rangle} \qquad C := S^{\langle 1 \rangle} \qquad T := S^{\langle 2 \rangle} \qquad P := S^{\langle 3 \rangle} \quad M := S^{\langle 4 \rangle}.$$

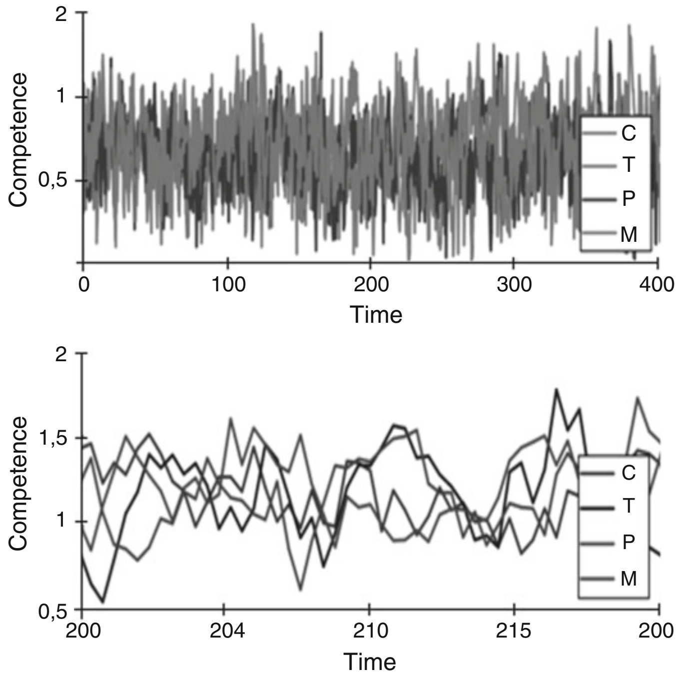

Fig. 2.2 The initial solution of the system

The solution is presented in two versions (Fig. 2.2). The first is over the entire time interval. The second is in the interval from 200 to 220. It is important that the solution depends on the number of passing points (the number of the system matrix inversion).

Next, we present the solution itself, but without taking into account random variables. The matrix of the system of equations:

$$D(t,\ \ Y) := \begin{pmatrix} A_C \cdot Y_0 + H_C(Y_0) \cdot A_{MC} \cdot Y_3 \\ A_T \cdot Y_1 + H_T(Y_1) \cdot A_{CT} \cdot Y_0 \\ A_P \cdot Y_2 + H_P(Y_2) \cdot A_{TP} \cdot Y_1 \\ A_M \cdot Y_3 + H_M(Y_3) \cdot A_{PM} \cdot Y_2 \end{pmatrix}.$$

Initial data:

$$S := \mathrm{rkfixed}(Y0,\ \ T0,\ \ T1,\ \ n,\ \ D).$$

We have calculated the variables for constructing the diagram:

$$t := S^{\langle 0 \rangle} \qquad C := S^{\langle 1 \rangle} \qquad T := S^{\langle 2 \rangle} \qquad P := S^{\langle 3 \rangle} \quad M := S^{\langle 4 \rangle}.$$

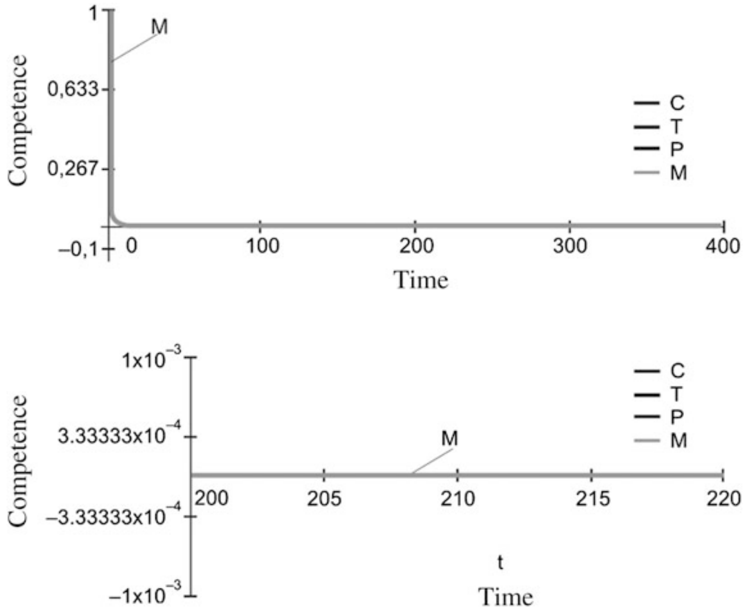

Fig. 2.3 The initial solution of the system

The solution is presented in two versions (Fig. 2.3). The first is over the entire time interval. The second is in the interval from 200 to 220. It is important that the solution of the problem tends to 0 and there are no oscillatory processes; all damp out instantaneously, even with a cyclical change in the coefficients.

Thus, mathematical models have been formulated for qualitative description of innovative economic processes and analysis of the proposed methodology reliability. It has been shown that under certain conditions a cyclical or spiral development of financing for innovative technologies and the growth of new consumer markets are witnessed. There have been derived main balance equations that take into account the effects of delay in the economic processes implementation described by the law of cyclical development of consumer markets. These balance equations can be used to qualitatively describe the processes under consideration, as well as to construct simulation economic-mathematical models for quantitative description. The proposed model is designed to assess the mutual influence of competencies and the rise of new consumer markets.

2.4 Application of the Law Relating to Correlation Between Competency Level and the Expansion of Consumer Markets

To demonstrate the application significance of the law on the correlation between the competencies level and the consumer markets expanding, presented in the form of a mathematical model described in the previous section, we will use simulation modeling based on a system of functional differential equations. In this system we use random factors, which we randomly simulate in the course of numerical calculation, namely we use the parameters presented in Table 2.4.

Using these parameters, we can numerically solve the system of functional-differential equations for the purpose of simulation. We use the numerical method to solve fourth order Runge-Kutta differential equations. As the result of this modeling we obtain the following graphs—Figs. 2.4, 2.5, 2.6 and 2.7.

Thus, Figs. 2.4, 2.5, 2.6 and 2.7 illustrates the solution to differential equations, reflecting irregular periodical fluctuations of the indicators, which are caused by the impact of random factors. In Fig. 2.8 one graph simultaneously shows the results of simulation modeling for the four selected indices, on the basis of this we can speak about a certain synchronization of periods of growth and decline in these quantities.

By this means, it can be stated that the demonstrated cyclicity reflects the correlation between the competences level and the growth of the consumer market throughout the time period under consideration.

It is noteworthy that the proposed model applies the constant values in hysteresis functions, therefore at different stages of the cycles; approximately the same maximum values of the indices were obtained. In fact, the maximum values of hysteresis functions tend to increase in course of time. Moreover, the economic growth is provided by the sophisticated technologies used to design new products.

Table 2.4 Characteristics of model parameters

Parameter identifier	Parameter value	Economic value
A_C	1	Diffusion coefficient of competency level
A_T	1	Diffusion coefficient of technologies
A_P	1	Diffusion coefficient of products
A_M	1	Diffusion coefficient of markets
H_min	1	Low value of hysteresis
H_max	1	Upper value of hysteresis
T_min	1	Low value of hysteresis
T_max	10	Upper bound of hysteresis
Fx	~R(0.7, 1.7)	Random influence
C (0)	1	Initial value of competency level
T(0)	1	Initial value of technologies index
P(0)	1	Initial value of products index
M(0)	1	Initial value of markets index

Fig. 2.4 Simulation modeling of the competencies level

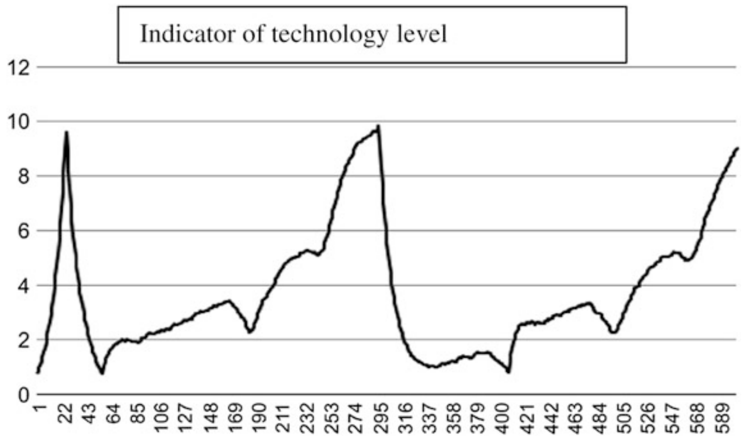

Fig. 2.5 Simulation modeling of the technology index

Respectively, high-tech companies need to constantly increase their investments into competencies.

Consider the results of simulation modeling in the case when there is a constant increase in the maximum values of the hysteresis functions, using a linear

$$H_{\min}(t) = \alpha t + H_{\min}(0)$$

and

$$H_{\max}(t) = \beta t + H_{\max}(0).$$

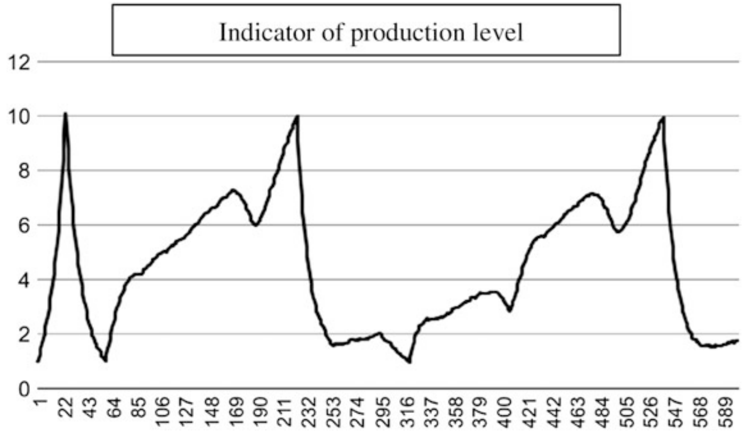

Fig. 2.6 Simulation modeling of the products index

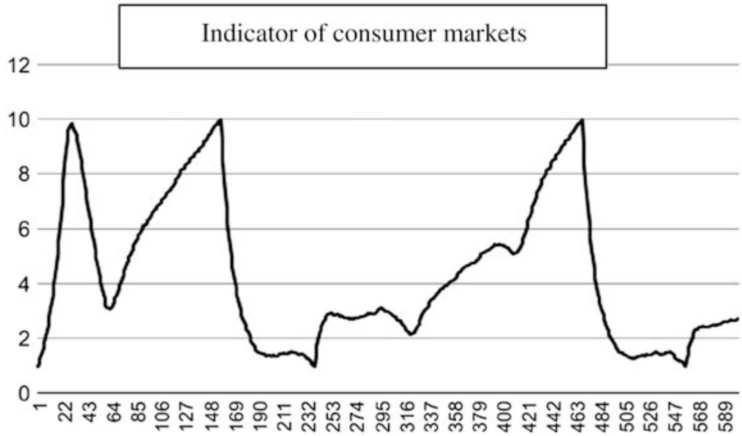

Fig. 2.7 Simulation modeling of the consumer market index

As the result of this simulation modeling we obtain the graphs—Figs. 2.9 and 2.10.

The results in Figs. 2.9 and 2.10 show that under the conditions of hysteresis functions growth, the influence of random factors decreases, at the same time they demonstrate the cyclical nature of changes in indices.

Simulation modeling shows that the proposed model for describing the correlation between the increase in competency level and the growth of consumer markets reflects various modifications in the dynamics of the basic values in the law "competences-technologies-products-markets". We can witness a certain cyclicity of these values changes, which describes the spiral growth of high-tech products markets based on innovative technologies that arise with increasing competences.

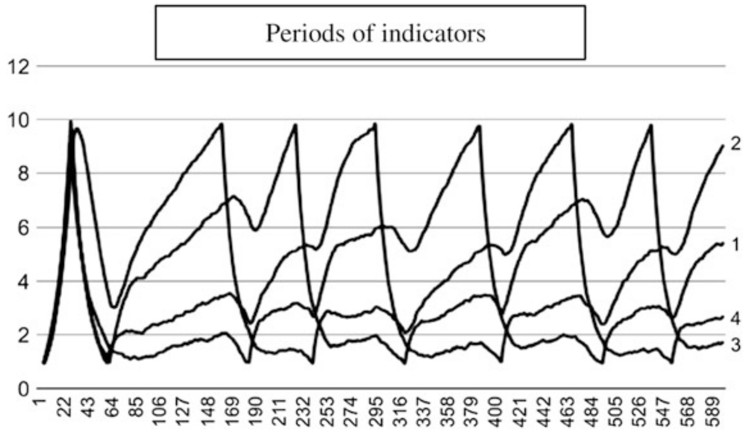

Fig. 2.8 Consolidated graph of simulation modeling of the law indices

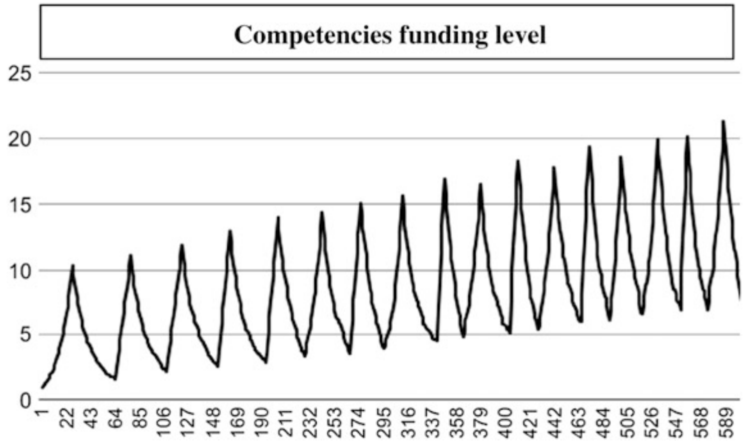

Fig. 2.9 Competencies funding level under the condition of the hysteresis functions growth

Law on cyclical correlation of competences level with the market growth
Consider balance equations for deriving a mathematical description of the law of the cyclical correlation between the level of competences and the growth of consumer markets. The first balance equation can be written in the following form:

$$M(t) = K(t)IC(t - h),$$

where IC (t) is the level of financing the increase in key technological competences for the creation of innovative technologies at time t. We consider both continuous time and discrete change of time depending on the problem posed.

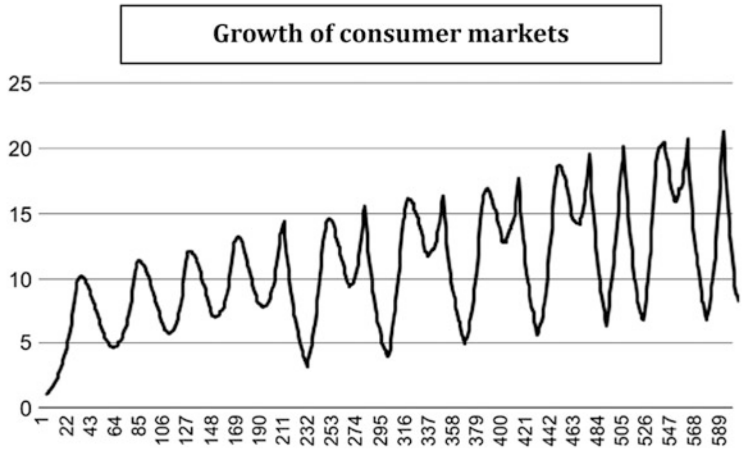

Fig. 2.10 Growth of consumer markets in the context of hysteresis functions growth

M (t) is a composite indicator of the consumer market, which is created as a result of the release of new products.

K (t) is a transition coefficient, the economic meaning of which is that it shows the growth of the consumer market, depending on the increase in financing the creation of key technological competences.

$h > 0$ is a time lag that reflects the fact that there is a time lag in the impact of financing key competences on the growth of the consumer market.

The second balance equation is written as follows:

$$IC(t) = L(t)M(t),$$

where L (t) is the coefficient of increasing financing the development of unique technological competences, depending on the increase in the consumer market indicator.

These balance equations describe a linear situation, although in reality these correlation should be written in a nonlinear form, since K (t) and L (t) depend not only on time, but also on the values of IC and M.

Comparing these balance equations, we can derive a common balance equation:

$$\frac{1}{L(t)}IC(t) = K(t)IC(t-h).$$

It is more convenient to write this equation without the division operation in the following form:

$$IC(t) = L(t)K(t)IC(t-h).$$

Consider the economic meaning of this equation and variants of its application in a practical assessment of the growth of financing the development of key technological competences. First of all, we have to note that this equation establishes the function of financing in innovative technologies and competences, depending on the initial conditions—the initial financing. Naturally, in a real situation this financing can depend on managerial decisions, but then the violation of balance equations means the inefficiency of investments.

Further one of the most important indices in the balance equation is the condition of:

$$L(t)K(t) > 1, \qquad t \geq 0.$$

The fulfillment of this condition means continuous growth of financing the development of key technological competences. On the one hand the violation of this condition shows that there is a constant fall in financing the development of key competences and, accordingly, the fall in consumer market indices.

As there is a cycle of growth and decline in of consumer markets, the transition coefficients L(t) и K(t) must change their values. A typical situation corresponds to the following conditions on the coefficients:

$$\begin{aligned} L(t) &< 1 \\ K(t) &> \frac{1}{L(t)}. \end{aligned}$$

This situation corresponds to the fact that financing the development of key competences is declining, but the growth of consumer markets is quite large. This situation is typical, because even with the constant growth of consumer markets, the financing of innovative technologies can reduce. Taking into account the effects of the delay in the growth of consumer markets from the amount of financing the development of key competences and technologies, this situation has an economic justification.

The linear models considered are adequate only at certain stages of growth (or decline) in consumer markets, since linear models can not reflect the situation of a sharp change in the economic situation, which can vary greatly in the markets of high-tech products. Therefore, it is necessary to consider more complex models that take into account the nonlinearity with the mutual influence of the financing level of key competences on the growth of consumer markets. Non-linear models can explain the emergence of the cyclical development of new products consumer markets created through the introduction of innovative technologies. We consider nonlinear models that reflect the fact of the consumer markets saturation. Indeed, any market has a certain capacity, so its extensions should have limitations that are expressed in the non-linear dependence of the coefficient K (t). In particular, we can use the following formula for this coefficient

$$K(t, M(t)) = k_0(t)\left(\frac{1}{1 + M(t)}\right)^{\alpha}.$$

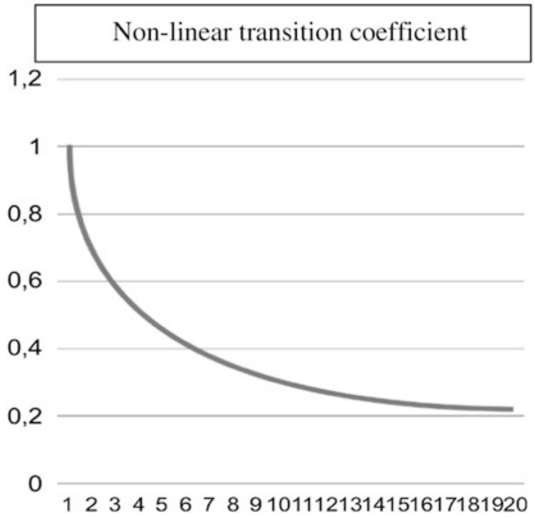

Fig. 2.11 Dependence of non-linear coefficient on M(t)

Here it is supposed that the degree indicator fulfill the condition $0 < a < 1$. In this formula, for the transition coefficient, we can see that for limited values of k0 (t) and with increasing value of M (t), this coefficient decreases, which reflects the marginal utility of the product. A typical form of this coefficient is shown in the following graph (Fig. 2.11).

Consider the numerical modeling of balance variables dynamics, with the use of non-linear coefficient. We use the following initial conditions:

$$\begin{gathered} I(0) = 1 \\ M(0) = 1 \\ L(t) = 2.5 \\ k0 = 2 \\ a = 0.5. \end{gathered}$$

These values correspond to the stage of rapid growth of financing key competences and, accordingly, to the rapid growth of consumer markets—Fig. 2.12.

The resulting graph shows that at the simulated stage, there is a rapid mutual growth of the balance variables, which, after reaching saturation, goes to stationary values. Obviously, in real economic processes, the stationary regime should also change to further growth (or decline), but since we used the coefficients in the balance equation that are independent of time, we are able to reach stationary values.

However, the results of this simulation demonstrate that with using non-stationary balance coefficients it is possible to obtain a spiral behavior of the dynamics of the balance variables that corresponds to the simulated law of mutual growth of the level of financing key competences and the expansion of new markets. The models under consideration provide only a qualitative description of economic processes, without a quantitative picture of these phenomena. A full description of

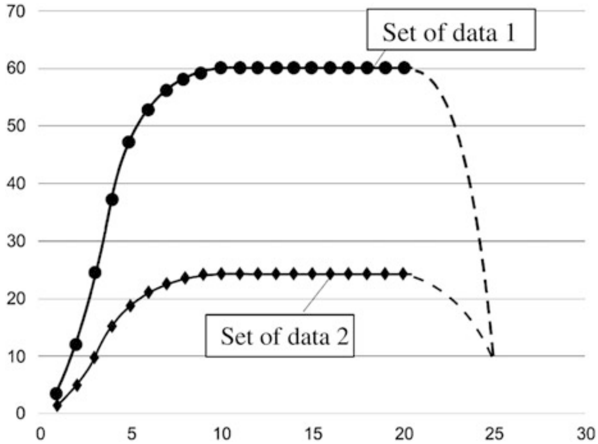

Fig. 2.12 Dynamics of balance variables

quantitative indicators in the law on creating new markets with the development of key technological competencies is possible with taking into account the specific features and relying on simulation models.

The economic law is presented, which is translated into the fact that the development of key technologies leads to the emergence of new consumer markets, resulting in a further increase in funding the development of key competences and the creation of innovative technologies. Thus, there emerges a spiraling mutual development of new technologies and the acquisition of new key competences on the one hand, and the creation and development of new consumer markets on the other hand.

The paper constructs the models the qualitative description of these economic processes. The proposed models are just the first results of the mathematical formalization of the law of mutual influence of the level of competences and the new consumer markets growth. These results open up new possibilities for investigating this interesting phenomenon. First of all, further research should include not only qualitative, but also quantitative economic and mathematical models. On the other hand, the derived balance equations can be applied to construct new economic and mathematical models in order to design models for optimal management of the consumer markets growth and the level of key technological competences. There have been derived main balance equations that take into account the effects of delay in the economic processes implementation described by the law on cyclical development of consumer markets.

The law of mutual influence of the level of financing key competences and the new consumer markets growth opens up new opportunities to investigate the most important economic problems of high-tech industries such as competitiveness management and increasing the efficiency of knowledge-intensive industries. Without solving these problems, it is impossible to ensure the effective functioning of the economy in the context of the global economic crisis and the economy restructuring into a modern knowledge economy.

Chapter 3
Approaches to Increasing High-Tech Corporations Competitiveness Based on Human Development

3.1 Modern State of Human Capital Theory

Publications on human capital showed extremely rapid growth, and the flow of research literature up to recent did not abate. It was capturing a wide range of areas, from the ability of various countries of the world to develop their human capital and the impact of human capital on the growth of gross domestic product up to the human capital of suicide bombers and the consequences of their attacks, and the human capital of same-sex families. Economics therefore often refers to "theories of human capital" rather than theory, or to a less binding "research program".

Followers of this theory are still asking the fatal question: "Human capital: a strict category or a metaphor?" The impressive fecundity and proliferation of hundreds of empirical research into various spheres of the economy nevertheless cannot hide the fact that "human capital" with its numerous derivatives ("investment in human capital", etc.) is not a theory in the proper sense of a word, but rather a scientific metaphor for a certain mosaic set of research programs which in fact can be based on a variety of theoretical premises, including mutually exclusive. The hopes that the results of such studies may by their nature be "fragments" that can be "folded" and "adjusted" in the future to form a reliable and verifiable unifying theory did not come true.

Since the human factor is always present in various economic, social, political institutions and behavior, there is a temptation to consider "human capital" as a homogeneous and universally applicable analytical framework. Pareto once prophetically remarked that there must be an "extraordinary wise-head who wants to replace political economy with psychology, since many economic phenomena depend on the desires and will of the people. Why is he limited to this? Why should economics not be replaced by geography or, say, astronomy? After all, the economic phenomenon also depends on the state of the seas, the location of the continents, the rivers and, by and large, the sun, which gives life to "this glorious world of plants and animals." Among such fabrications there are also proposals to consider the

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economics a positive science. This activity is laudable, because it causes laughter, and the laughter improves well-being."

Assessing any set of scientific views in the context of its claims to the status of theory, it is necessary to understand (not the same as to share) its original (basic) theoretical positions. If there are none, then inevitably there arises "an idea of the extreme divergence of approaches" among scientists and human capital specialists. Because of this extreme divergence in this issue, complete clarity is necessary. But many economists behave as if the original postulates do not play a big role in the formation of an enterprise that insistently claims to be a "science".

They tend to avoid discussing the methodological problem. This is due to the fact that the human capital theory in its authentic form is based on the principles of the neoclassical school (methodological individualism, limited rationality, maximization, equilibrium of the economic system, etc.). Therefore, it is true that if a researcher does not share this approach then he actually develops some other concept. It would be then appropriate to refer not to "human capital", but "the labor force", "human potential", "labor potential", "collective laborer", etc.

The inflation of theory entails a serious problem of the reliability of measuring cost, quality and efficiency of human capital. It is noted that "there are no generally accepted approaches to measuring the human capital and its intrinsic nature as an economic category. In addition, the complex and synthetic concept of human capital is differentiated: individual HC, corporate, national." In this situation, it is not surprising that the assessments of human capital often contradict each other radically. For example, "dependent on author and source the value of human capital differs in degree." There is a strong influence of a well-known tendency to confuse the subject of research with a set of research methods. The result is such studies are imperceptibly reduced to statistical procedures where only careful study of the methodology and its application accuracy are required to ensure the expected results.

As has been the case on many occasions, here the methodology defines the research issue, and the infinite accumulation of mosaic data does not add anything to understanding of economic patterns. This flawed "style" is unmistakably recognized in the range of selected data sources and the way they are processed, as well as in the professional jargon its modern followers use. The economic and political conditions for the emergence of a human capital theory, as a rule, are not considered in the scientific literature. This style, which can be called "abstract empiricism," took shape in the US economic science and sociology in the late 1950s and early 1960s, with the emergence of a mass consumption society and the unexpected appearance in the US market of a dangerous competitor—Japan.

Its eminent academic figures were Gary Becker in the economy and Paul Lazarsfeld in sociology (both worked at Columbia University in the 1960s, later Mr. Becker became professor of economics and sociology at the University of Chicago, where he cooperated with Jacob Mincer, who is considered the founder of the modern labour economy, and Theodore Schultz, the creator of IMF and World Bank policy of investment in third world educational institutions).

Representatives of this style, as a rule, do not disclose or realize that they adhere to certain methodological grounds, but at the same time tend to present their approach as "strictly scientific." They do not bother about the origin of their methodological skills unless any circumstances compel them to do so. For example, the requirements for applicants for academic degrees.

Despite the fact that "empiricists" of all shades tend to avoid scientific debate on "Where Is your Utopia?", we all have the opportunity to dig down to its metaphysical core.

First, the "Human Capital Research Program", as it is formulated by T. Schultz, G. Becker and D. Mincer, is characterized by "methodological individualism." That is, the initial assumption that all social phenomena must be traced to their foundation in an individual behavior For the "fathers" of this program, the creation of human capital is understood as the "work of individuals acting in their own interest."

Second, this approach was a typical example of so-called psychologism, i.e. an attempt to explain social phenomena with facts and theories relating to the properties of individuals As C. Wright Mills said, psychologism "rests upon an explicit metaphysical denial of the reality of social structure. At other times, its adherents may set forth a conception of structure which reduces it, so far as explanations are concerned, to a set of milieux."

Third, the subject of "individual activity" itself was constructed by the fathers of the human capital theory on the basis of the metaphysical assumption that all human behavior is literally characterized by the fact that "participants maximize usefulness in a stable set of preferences and accumulates optimal amounts of information and other resources in many different markets." G. Becker believed that "economic approach is unique in its power, because it can provide a unified framework for understanding all human behavior."

Although G. Becker and his followers in their numerous works refer to certain positivistic criteria of scientificity, they themselves everywhere violate the neo-positivist principle of verification of theories and the principle of falsification introduced by K. Popper, the advocate of Open Society. According to the latter the refutability of theories by facts of science is recognized as the criterion of the scientificity and the way to demarcate empirical sciences from metaphysical approaches. All this, without any indiscriminate criticism, shows on which side of the demarcation line between scientific theories and what science is not, is the human capital theory. The ideological empiricism has created an atmosphere of controlled "intellectual chaos", in which all the benchmarks and criteria for this demarcation have disappeared.

As postulated by G. Becker, "linked all together the maximizing behavior assumptions, market equilibrium and stable preferences, when conducted firmly and adamantly, form the core of the economic approach ... They lie at the heart of many of the theorems that grow out of this approach." Having created his "Homo consuming", G. Becker, and behind him a whole army of followers, believed that "the economic approach is a comprehensive one that is applicable to all human behavior, be it behavior involving money prices or imputed shadow prices, repeated or infrequent decisions, large or minor decisions, emotional or mechanical ends, rich or poor persons, men or women, adults or children, brilliant or stupid persons, patients or therapists, businessmen or politicians, teachers or students".

Further, in full accordance with this logic, the "economic approach" not only "reinterpreted" various forms of behavior in a language familiar to economists, but rather presumptuously invaded with its metaphors into the most diverse spheres of social sciences: family, education, religion, state, politics, crime, etc., often in complete disregard of theories developed in these areas. For example, in the main works of G. Becker, D. Mincer and T. Schulz there is not a single reference to the well-known concepts of two outstanding representatives of the same University of Chicago: the concept of "conspicuous consumption" of economist and sociologist Thorstein Veblen and "white collar criminality" of criminologist and sociologist Edwin Sutherland.

Since this is a theory of the object, it is not possible to draw more from the most detailed empirical study than was laid in the initial phase. Only information can be obtained from the study itself. How it will be used depends on whether or not specific empirical studies have been a test of some theoretical constructs. The allegations are not verified or specified, they are simply adjusted to the figures with the use of statistical procedures and combined with other unverifiable allegations.

Although G. Becker's "economic imperialism" was rewarded in 1992 with the Nobel Prize "for extending the scope of microeconomic analysis to a whole series of aspects of human behavior and interaction, including non-market behavior," today, according to B. M. Genkin, "when "the years passed and the passions subsided", we can state that rumors about the scientific and practical value of the human capital theory turned out to be greatly exaggerated." Becker is left with the merit of "developing calculation schemes by analogy with the analysis of investments in technological capital", but in this case, there is no trace of "economic imperialism". It is indicative that in many modern scientific works and educational literature on disciplines such as the economics of labour and labour sociology, there are no references to the concept of human capital and its adherents achievements, or they are referred to in passing.

In the Soviet era, labor economics and the sociology of labor monopolized the evaluation of this theory. As party sciences they acted from Marxist methodological positions. Theories of marginal utility and marginal productivity were portrayed as "vulgar". Criticism of the theoretical foundations of the human capital concept began with the formulation of the question of the legitimacy of the analogy between human capabilities and physical capital, between labour forming processes and material means of production. The question was followed by a detailed negative response in terms of Marxist economic science. In the words of R. Kapelyushnikov, "the mistake of bourgeois economists stems from ignoring the fact that capital is not just a stock of goods, but also a certain social attitude that emerges from this stock."

The Soviet sociology of labor has developed a scholastic approach that has become a kind of standard of scientificity for research on labor motivation. It was based on three dogmatic grounds: human nature, needs and satisfaction with work. The sociology of labor under the influence of this false theoretical perspective did not even raise the question of the legitimacy of its methodological grounds in its empirical studies. As the author of the "desk book" of Soviet sociologists, The Man and His Work, V. A. Yadov said in one of his interviews, "we had Marxism, but no structural functionalism. So, it was dragged along on the sly!"

An irony of fate is that today Marxism is dragged along to cover up white spots of neoclassical theory with it. As A. V. Koritsky states, "an unbiased researcher can say with good reason that K. Marx is one of the major predecessors of modern developers of the neoclassical human capital theory."

The tone of the discussion changed after 2008, when theories and models that prevailed in foreign economic science and practice, which many economists and sociologists revered, demonstrated their insolvency in the face of world financial and economic crisis and a prolonged recession. As MTI Professor R. Solow said at one of the proceedings in the US Congress, the models based on this ideology were "internally doomed to failure", so they could not pass a "credibility test." Since Becker's theory and its numerous derivatives are inextricably linked with the ideology of "rational choice", they inevitably had to share its fate.

Understanding of how human capital affects the competitiveness of the national economy makes it possible to concentrate resources in strategic socio-economic policy planning. Theoretical and political agreement on the importance of human capital to enhance competitiveness inevitably leads to another problem: How important is human capital for the competitiveness of national economic models compared to other factors? Comprehensive theory, as well as an exhaustive list of indicators of human capital that has an impact on competitiveness, do not yet exist. Many elements are identified today, but the link between them and national economy competitiveness yet to be proved. The following paragraphs of the monograph are dedicated to this issue.

3.2 Building Competitive Advantage on the Basis of Human Capital Development

Searching for a competitive advantage, organizations strive to identify their own capabilities and untapped capabilities on which it will be possible to build business space. Identifying and developing internal resources and capabilities become the ground for creating the organization's competencies. Under these conditions, the expansion and use of competencies make economic sense, because this increases the cost of the organization in the market. It is important to bear in mind that the effectiveness and significance of acquiring and developing the competency of an organization are not universal categories: they are defined and self-grow only in the context of a specific strategy for the company development. The organization' competencies are most successfully developing in the course of purposeful activity to create new products, organizational and structural actions for the development of new niches in commodity markets, which ensure high competitiveness of the manufacturing company. In so doing to create competitive products based on key competencies of the company it is necessary to line up a process of managing all available knowledge within it. To this end, high-tech companies should create competence and innovation management centers.

Establishing a center for the data collection and dissemination—the competence and innovation management center—is one of the tasks faced by the organization, where it was decided to single out and describe such a resource as knowledge. Currently, there are many definitions of the concept of "competence and innovation management center". At the same time, some researchers characterize it as a special structural unit of the enterprise that controls one or several areas of activity important for the company, accumulates relevant knowledge and seeks ways to get the maximum benefit from them. Other researchers define it as a special structural unit of the organization, whose function is to monitor the most important areas of activity, collect relevant knowledge and find ways to use them as effectively as possible. There are some other scientists who consider the activity of the competence and innovation management center as an activity for competency accumulation and systematization.

In the context of our research, the competence management center is a special structural unit of an organization the function of which is to monitor the competencies in the most important areas of activity, collecting relevant knowledge (within the company or on the market) and finding ways to use them as effectively as possible. Establishing competency and innovation management centers can be a tool of accelerated development of unique competencies, including available on the market.

The role of the competency and innovation management center is to ensure the integration of knowledge and processes, to provide access to experts and information resources for all stakeholders (employees, management, clients, partners) and to create effective communications. In other words, the competence and innovation management center ensures that people's communication with each other and obtaining information they need to work effectively. Thus, the competency and innovation management is an example of an external source of competency acting on the outsourcing (internal or external) principles.

Sometimes the competence and innovation management center is built around a sophisticated, expensive or unique production facility, the operation of which is also a skilled work.

In general, the work of the competency and innovation management center implements the following functions (all or a subset):

– Monitoring of the current state of knowledge management in the organization and provision of relevant materials, from which users will be able to learn where they can get the knowledge they need, and management—to draw conclusions about the effectiveness of this direction;
– Identification, formalization and dissemination of implicit or new knowledge of the organization;

– Tracking of technological innovations and the emergence of new trends in a given area;
– Collection and description of the knowledge obtained by the company in the course of implementing specific projects;
– Management of knowledge bases of the organization: their maintenance, updating, integration, development of convenient search engines or card files;
– Communication among users and experts who possess the required expertise:
– Protection of the company's intellectual property;
– Training of new employees in the organization, sharing experience;
– Dissemination of accumulated knowledge throughout the organization either on it on initiative or upon the request.

The establishing of a competency and innovation management center requires much effort and resources. It is true even when the center is established on the basis of the existing organizational unit. However, its operation can provide considerable benefit to the company: preserving and increasing the most important knowledge, maximizing the effective use of human and intellectual capital, optimally distributing experts' time, and finally, solving many business problems at the expense of the organization's own potential.

The model of competency and innovation management center can be used to solve the key problems no matter what the situation on the market is. Experience shows that this model is in high demand in two cases: First, when companies are rapidly expanding and do not have sufficient internal resources to carry out all strategic programs using their own resources. At the same time, the company's success on the market directly depends on the speed and quality of these initiatives implementation. Then the main function of the competency and innovation management center is the formation of new competencies, or their attraction from outside. The second case is the situation when companies experience severe staffing restrictions, for example, as a result of slowing down in growth rate and limiting capital investments. In such cases, it is impossible to unequivocally predict the need for resources essential for implementing the critical programs that are planned by the company. In this case, a center is established that, in effect, performs internal outsourcing functions for the tasks of various divisions of the company, whose specialists and capacities can be transferred from one department to another as and when necessary.

At the same time, the analysis of recommendations on the configuration of competence management and innovation center allows identifying the main functional blocks in the organizational structure of the public competency management center, namely:

– A block of functional support that includes telephone consultation, user messages processing, work with a solution database, the analysis of emerging problems;
– A block of system technical support that provide solution to technical problems, the analysis of roots of technical problems, and system administration;
– A block of information resources management that provides the distribution of information materials to users, review of information sources, access to

information sources for people concerned, preparation of specific information on requests, and organization of information events;
- Extra research control, providing management of user requests for carrying out research, development of new solutions and programs;
- A block of inner marketing management of the system. The formation of content for explanatory materials concerning implementations and solutions, presentations, information events for future users, and of reference visits;
- A block of training that provides the development of special educational programs, standard classes for groups of users and training project teams.

The modern dynamically developing external environment requires the development of new competencies of companies in various fields. The issues of shaping and managing competitive advantages of the company as well as the choice of competencies are problem in the field of strategic management that is most frequently discussed by theoreticians and practitioners. The success of an enterprise in the context of the current level of competition virtually on all markets is determined by the ability to promptly develop innovative competencies.

The set of key competencies is formed due to integration and combination of various resources of the enterprise and attraction of external resources. At the same time, as it was defined in the previous paragraph, knowledge and human capital of the organization represent one of the key competencies of any organization, since the employees of the organization are the competencies bearers. However, often high-tech companies face serious problems: the lack of specialists of the required qualifications, the inability to expand the company's staff and the complications of institution building. Various implemented professional tools used for shaping unique competencies will provide the state-of-the-art solution to these problems.

On the whole, the knowledge management system of the organization represents a set of methodological approaches, technologies and mechanisms that allow the management to use knowledge to create additional values for customers. It is an ongoing process that always accompanies innovation development.

The development of capabilities and competencies, as well as their implementation in final products and services, requires the formation of new approaches to management, including the introduction of new processes, procedures, technologies and methods, restructuring staff interaction, maximizing their involvement in planning activities and making managerial decisions.

It is known that in the short term the competitiveness of a company depends on the price and quality of its products, but in the information society, when there are common standard requirements for products, equipment and technologies of the same type are used, it becomes difficult to stand out on the market. Of course, a company can take advantage of a temporary favorable situation and become a leader, but all factors of a temporary competitive advantage are usually accidental results of sheer luck in the external environment and can easily be repeated by competitors.

In the long term competitiveness is ensured by the competences and resources development. And this should be done before competitors with lower costs will be able to do it. These purposefully administered factors of the company's internal environment create sustainable long-term competitive advantages in the form of the ability to provide the consumer value of products, uniqueness, and novelty. These factors are difficult for competitors to copy and, therefore, guarantee long-term superiority.

The real sources of leadership of a company in a certain area are the ability of its management to transform technologies and skills into competencies that increase adaptive capabilities.

Knowledge management is the organizing of cyclical process that can be presented as it is given in Fig. 3.1.

This process combines specific intangible resources (knowledge) and the ability to create them, and the continuity of the knowledge management process ensures the maintenance of competency at the required level. Otherwise, the knowledge-based company will quickly lose its competency.

Maintenance and development of competency is the main aim of knowledge management in the organization. Changing competences always takes time, as it involves acquiring new knowledge and developing the company's resources. At the same time the resources have to meet some requirements and be used in a particular combinations. There are "compulsory competency" of technology, management system, IT resources, without which the company is not viable at all.

Competences, as internal knowledge, are inaccessible to the direct perception of the consumer. They are reflected in the growth of the use-value of the final product or service.

According to the resource concept, a successful strategy relies on key competency. It was not enough to possess basic resources, uniqueness is needed. But not every company has it formed. Otherwise, the efforts of companies are aimed at using short-term competitive advantages. Under these conditions, it is necessary to build a

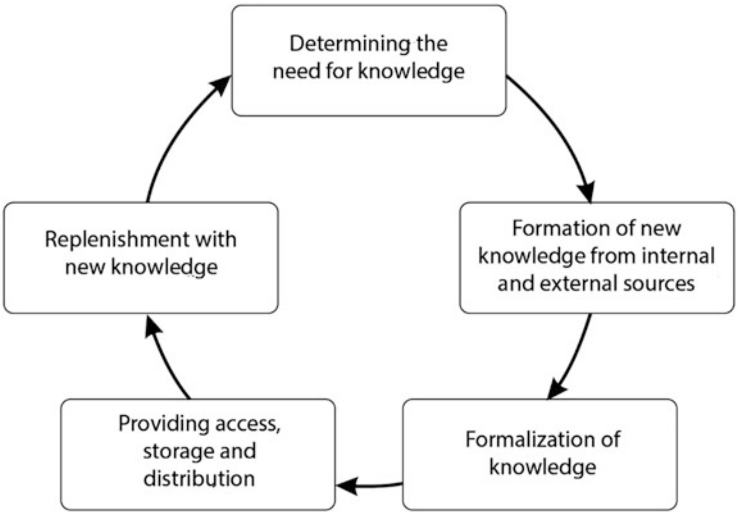

Fig. 3.1 Knowledge management process within the company

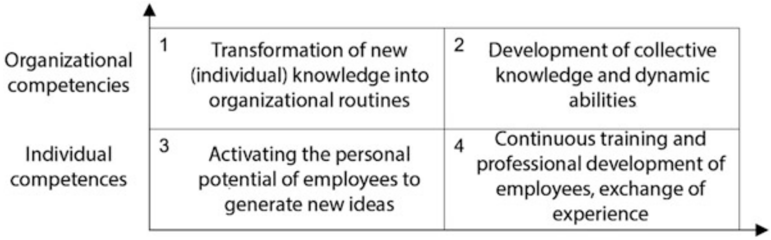

Fig. 3.2 Strategies for knowledge management. Source: Malygina O.V. Formation of the organizational competency in the knowledge management system: the thesis Ph.D. in economics Moscow, 2010

system that would motivate knowledge bearers to create and exchange knowledge, as well as to form an organizational culture. It is important to identify the relationship between the knowledge of the basics of business, which becomes the ground for creating value for the consumer. Then the main stages comes to the foreground: acquiring and harnessing new knowledge.

When developing the company's strategy, the main effort should be concentrated on the process of knowledge management and this will create conditions for increasing the level of the company's competency.

Figure 3.2 shows possible strategies for knowledge management. The choice of knowledge management strategy is determined by the following criteria:

– The focus on generating new knowledge, or accumulating existing one;
– A reference point for the development of individual or organizational competences.

The strategy, placed in the table field 1/3, is aimed at the use of new knowledge with a focus on new competencies. As a rule new knowledge first is acquired by some of the employees and then it is transformed into a collective knowledge. It is important to solve the problem of managing the personal potential of employees: to ensure their training, as well as to develop management functions to transform new knowledge into organizational competencies. This strategy requires defining the boundaries of the value of acquired knowledge, since the formation of competencies can occur only on the basis of valuable knowledge.

The strategy, placed in the field 2/4, on the contrary, is aimed at the formation and development of competencies through the identification of already existing information, which is collected in one form or another in the team. With such a strategy, the development of the dynamic abilities of an organization based on the identification of the implicit knowledge of individual employees becomes a development priority.

The employees' knowledge is a key resource of the enterprise, but in many companies they are obviously not used enough, therefore it is important to initially determine the main principles of work and tasks of competence and innovation management centers. They should facilitate the identification of practical work skills, which are subject to further reproduction. This requires solving the problem of formalizing knowledge. It is well-known that he solution to many problems is at the intersection of different fields of knowledge, the search for an effective engineering solution often requires agreement with economists and managers, and, conversely, many managerial decisions conflict with the views of engineers, and this requires combining and applying the accumulated knowledge in a new situation. All of these problems involve creative search and constant questioning.

Competence management is an integral part of the knowledge management system and should be built along with other components. The data on already formalized knowledge is input in the generalized process of knowledge management. These are available patents, licenses, technologies and other intellectual property objects belonging to the company. This knowledge already has a generally accepted classification system for scientific fields (see the classification system for patent information). At the same time, the implicit knowledge of individual employees and teams should also be included here.

The executors of such work in the organization can be knowledge engineers and experts in subject areas. Graphically, this model of knowledge management is shown in Fig. 3.3.

The general goal of such a system is to formalize and classify all available knowledge in the organization with the possibility of their search for it.

Decompositions of the generalized process of knowledge management reveals five basic processes:

– Knowledge creating;
– Knowledge identifying;
– Knowledge organizing;
– Access to knowledge;
– Knowledge harnessing.

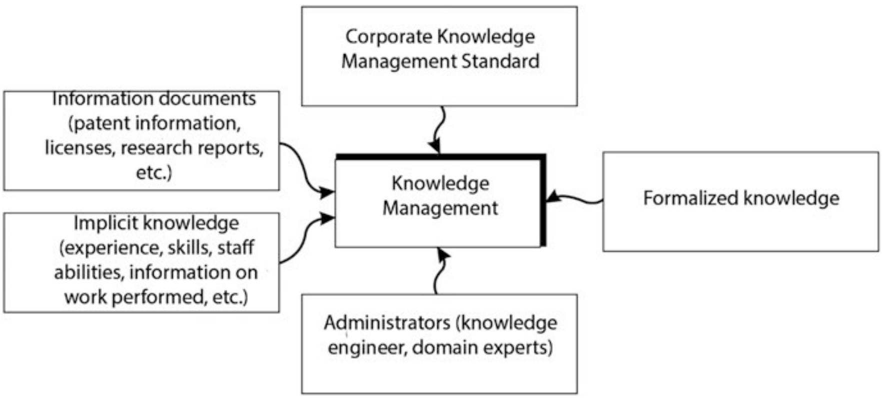

Fig. 3.3 Forming a knowledge management model

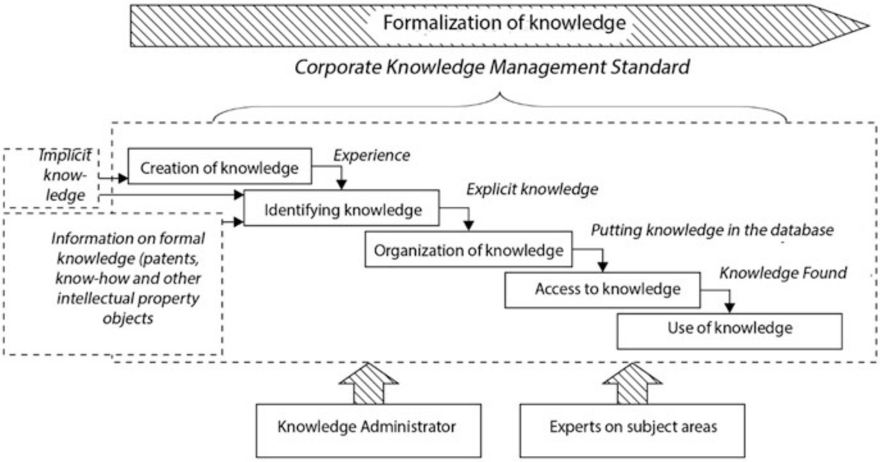

Fig. 3.4 Processes of knowledge management

The decomposition the above given knowledge management process is shown in Fig. 3.4.

Thus, it becomes obvious that knowledge management is the basis of the process of forming the organization's knowledge, in this regard, in order to ensure sustainable competitive advantages of the organization, it is necessary to develop an algorithm through which it will be possible to identify the core competencies of organizations through competence and innovation management centers. In general, the algorithm can consist of the following steps:

1. Collection and analysis of information on the status and trends in the organization and the environment;
2. Development of a corporate-wide method of describing organizational, managerial, production and scientific-technical competencies through special Competence cards (Questionnaires for the identification of competencies), and fixing them in corporate regulations;
3. Filling in the Competence card (Questionnaire for the identification of competencies);
4. Assessment of technical and economic conditions for product updating based on the competency under study;
5. Assessing the competency correspondence with the world level of science and technology;
6. Making decisions on further development and investment in the development of certain competencies for the projects implementation in the civil sector;
7. Making decisions about the localization of competencies (for example, in competence and innovation management centers, in intra-corporate start-ups, etc.);

8. Implementing the measures to strengthen and protect existing competencies (through such means as, for example, limiting the possibility of transferring specialists from priority projects);
9. Searching for missing competencies on the market, including through a request or an "order for innovation" through a corporate portal ("Competency Exchange");
10. Evaluating the effectiveness of activities in the management of core competencies.

In detail the proposed algorithm can be described in the diagram in Fig. 3.5.

Thus, the general logic of research on the steps in the process of managing the competencies of enterprises in high-technology industries should be as follows:

- Analytical step;
- A step of preparing and making decisions;
- A step of implementing decisions;
- A step of evaluating the effectiveness of the decision and its adjustment, which terminate the cycle, returning the process to the first step.

At the same time, the competence and innovation management center should closely cooperate with state authorities, as well as with higher educational institutions, on the basis of which centers for training and raising the level of expertise of the expert community operate.

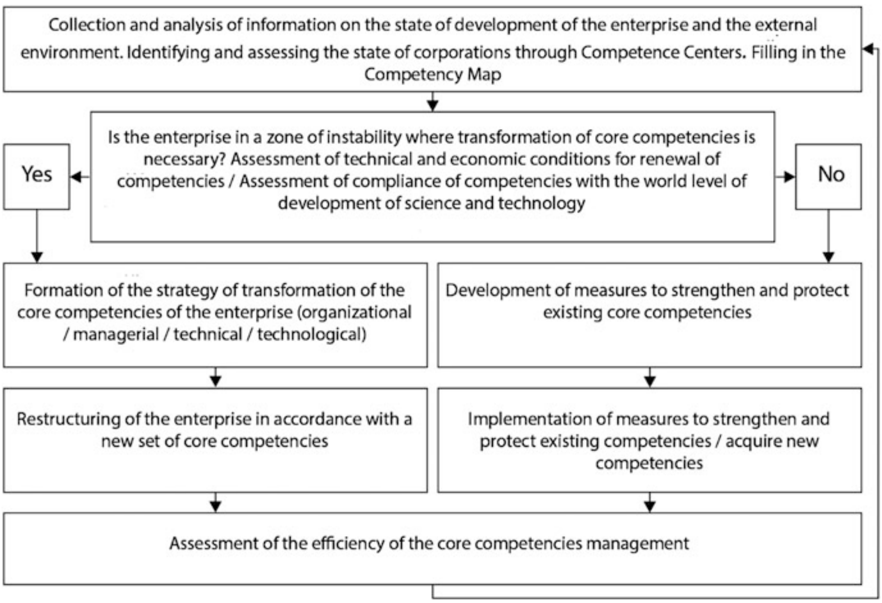

Fig. 3.5 Competency management process model

A number of large holding companies, in order to form an effective knowledge management system, have embarked on the creation of corporate training centers (corporate universities) focused on knowledge management and their application in the development of new products and services, and in training personnel for new tasks. The examples are Motorola, Severstal and many others.

An example of a corporate university is Motorola, which consists of 99 units in 21 countries with a permanent staff of 400 employees. Motorola Corporate University exists as an independent business unit of the company and offers its training services not only to other units and structures that are part of Motorola, but also to third parties. At the heart of this educational system is a huge database, containing the knowledge that has been accumulated for the entire lifetime of Motorola.

3.3 Multi-criteria Evaluation of the Corporation Human Capital Effectiveness

The ultimate goal of the most organizations development is to achieve a sustainable competitive advantage, the sources of which are, according to the resource theory, the company's internal capabilities. Today the most important resource of the organization is people as bearers of certain competencies, as well as teams that bear corporate culture and create synergetic effects of combining individual knowledge and abilities in a single organizational, information and legal field. A generalizing indicator of the domestic resources development can be human capital. The ability to effectively use and develop human capital is one of the most important organizational competencies of knowledge-intensive companies. These competences are not directly related to products and technologies, but form the basis for their production. This relationship of competencies with human capital allows us to apply to the study of the organization's activities a number of provisions applicable to the assessment of human capital. The growth of human capital can summarize the effectiveness of investments in the development of competencies.

A comprehensive theory, as well as an exhaustive list of indicators used to measure human capital, which has an impact on competitiveness, does not yet exist. Many elements or "variables" of human capital have been identified in the academic literature, but the relationship between these elements and competitiveness has yet to be established and measured, which seems to be an important field of research.

The choice of both objects and methods of measurement is determined by the initial theory of human capital. Comparison and distinction between theoretical and practical variables, for example, the correlation between human capital and productivity, and especially the establishment of functional links between them, is a serious problem, since economic theory can be adopted only if it quite clearly determines the relations between economic variables and observable facts, i.e. real variables.

The discrepancies between theory and real case scenario significantly affect the quality of human capital concepts in economic science. In this context, we have to outline human capital research (both theoretical and empirical) confining it to the opportunities that can provide corporations and enterprises of knowledge-intensive industries with competitive advantages and unique productivity.

To determine the organization, where the human potential is used most effectively, the methodology of rating multi-criteria evaluation is appropriate.

By the methodology of rating multicriteria evaluation we mean a set of methods and principles used for solving the metatask of a multicriteria rating evaluation of the human capital effectiveness in companies; the stages of this evaluation can be represented in the form of successively solved specific problems of diverse complexity.

The metatask of a multi-criteria rating is decomposed into successively solved specific subtasks, presented in Fig. 3.6.

The process of evaluating the quality and efficiency of objects of an arbitrary nature is preceded by the formalization of the subject in accordance with the principle of the system approach—multimodality.

At this stage there used the following research methods of system analysis, namely: multi-level classification, decomposition and composition of objects of research, modeling of technology activities.

The advantages of the system approach and analysis are the holistic representation of any problem as a larger whole, the comprehensive study from various points of view, the multilevel description at various levels of complexity and detail, the consistency of the various levels, the dynamism of considering all elements, taking into account their temporal variation. The system approach does not reject the use of intellectual judgments of individuals, but requires their verification by expert evaluation methods in combination with multi-model research.

The structural and functional description of the system and objects can be considered both in statics and in dynamics. Statistical analysis results in the basic set, the enumeration of the main elements of the system at an arbitrary fixed timepoint. The dynamic examination makes it possible to reveal the change patterns of elements in time, the life cycle of the system, its origin and source of origin, formation and development, history and future. For scientific cognition and management of any system or objects it is necessary to know how the given system originated, what the main stages in its development were, what kind of system it is now and what are the trends and prospects for its development.

The disadvantage of the system approach is its non-constructivity. The recommended principles are of a general nature and do not provide a sufficiently clear guidance for solving specific problems. Typically, the descriptions of systems and objects are carried out by informal methods based on developers' experience and insight.

The results of the subject modeling can be structural and functional interaction models, the description of business processes, taking into account various restrictions—resource, money, time, etc., the composition of indicators for assessing the quality and effectiveness of research objects, as well as the model of the

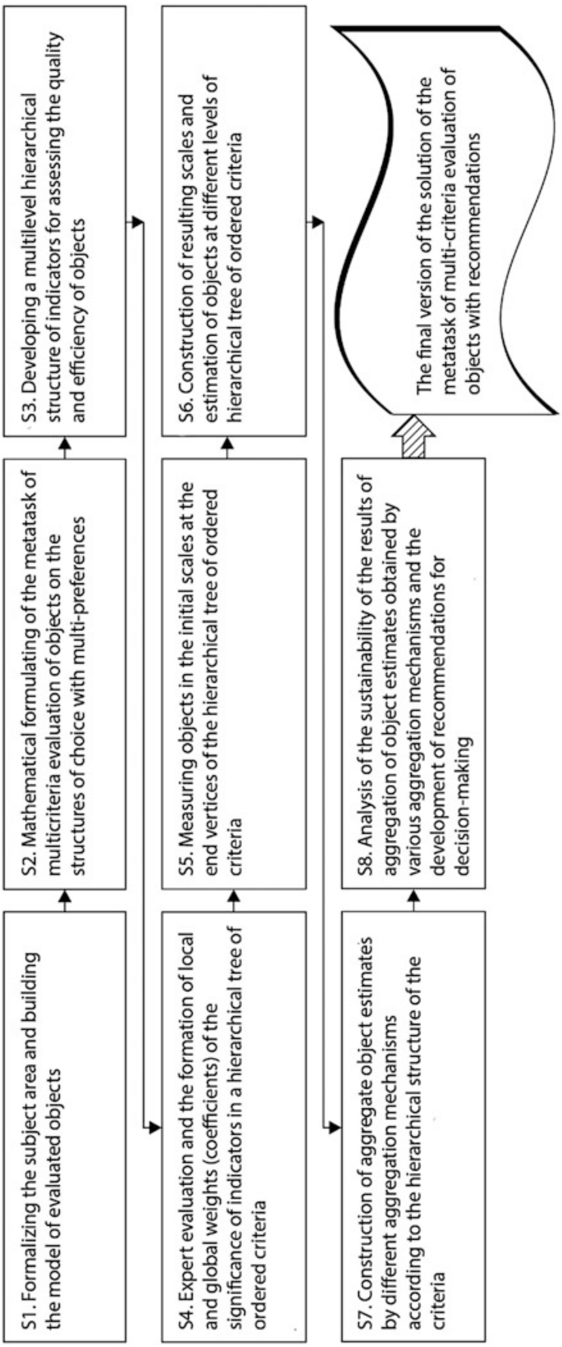

Fig. 3.6 Stages of multi-criteria rating. Source: Tyulin A.E., Ozhiganov E.N., Korneenko V.P. Methodology of the rating evaluation of the human capital effectiveness. Economics and Entrepreneurship. 2014. issue 12. Ch. 3. p.p. 183–191

effectiveness of the use of human capital in corporations and enterprises of high-tech sectors of industry.

Mathematical rating multi-criteria evaluation of the human capital effectiveness will be carried out using the example of corporations in the aerospace industry. In the context of this evaluation, a number of problems arise, related both to the initial concept of human capital, and to finding and accessing indicators of multi-criteria evaluation.

Table 3.1 presents the comparative indicators of labor efficiency of leading companies in the US aerospace sector—revenues and incomes per employee.

Within the framework of the task, corporate management performance indicators, including the return on investments (ROI), can be useful.

The multicriteria problem with several objective functions is written as follows:

$$f(a_l) = \left(f_1(a_l), f_2(a_l), \ldots, f_{n_F}(a_l)\right) \rightarrow \underset{a_l \in A}{\text{extr}}, \tag{3.1}$$

where $A = \{a_1, a_2, \ldots, a_l, \ldots a_{n_A}\}$—a finite set of admissible alternatives (objects, variants);

$x_j^{(l)} = f_j(a_l)$—evaluation of the product $a_l \in A$ according to the criterion f_j in the initial quantitative or qualitative (order-point) indicators;

$l \in J_A = \{1, \ 2, \ldots, n_A\}$—set of numbers of objects (products);

$j \in J_F = \{1, \ 2, \ldots, n_F\}$—set of criteria numbers.

The problem (3.1) is sometimes called the vector optimization problem, since a vector objective function that takes values in the corresponding space is introduced into consideration. Such problems are a special case of a vast class of choice problems with many preference relations, and their solution becomes possible provided that one or another principle of constructing the resulting preference relation is involved. One of the most widely used and well-grounded principles is

Table 3.1 Comparative indicators of labor efficiency of leading companies in the US aerospace sector

Company	Earnings/employee (dollars)	Income/employee (dollars)
Lockheed Martin Corporation	394,717	28,301
General Dynamics Corporation	319,333	24,240
Northrop Grumman Corporation	367,963	31,256
Boeing Company	516,508	29,891
L-3 Communications Holding, Inc.	200,623	22,311
Raytheon Company	338,068	32,050
Honeywell International, Inc.	308,603	32,290
Rockwell Collins, Inc.	265,519	33,443
Harris Corporation	358,000	38,157
Science Applications International Corp.	292,769	9,462
Mean value	355,027	26,098

Source: CSIMarket

the Pareto principle. With this approach, a set A^{nd} of unmodified (Pareto-optimal, effective) solutions can be taken as a solution to the vector optimization problem, which consists of objects $a_l \in A$, for which there are no objects a_l, dominating them with respect to Pareto:

$$A^{nd} = \left\{ a_p \in A | \neg \ \exists \ a_l \ \left(a_l \succeq a_p \right) \right\}, \tag{3.2}$$

In the event that the partial criteria f_j are to be maximized, the dominance relation $\overset{\pi}{\succeq}$ of the Pareto object a_p over the object a_l is determined in the following form:

$$a_p \overset{\pi}{\succeq} a_l \Leftrightarrow \forall j \in J_F : f_j\left(a_p\right) \geq f_j(a_l) \ \text{ and } \ \exists j_0 \in J_F : f_{j_0}\left(a_p\right) > f_{j_0}(a_l),$$

i.e. the object a_p dominates the object a_l according to Pareto principle, the score $f_j(a_p)$ of the object a_p is not less (or more) than the score $f_j(a_l)$ of object a_l and at least one inequality (3.2) is executed as strict. The set of estimates characterizing an object $a_l \in A$, is often called the profile of the object a_l i.e. each object a_l can be associated with a vector of estimates

$$\left(x_1^{(l)}, x_2^{(l)}, \ldots, x_{n_F}^{(l)} \right), \ \ \forall l \in J_A.$$

Since in most cases the number of effective solutions in the set A^{nd} is large enough, it becomes necessary to narrow the Pareto objects $a_p \in A^{nd}$. In this case, the problem of aggregating and ordering the Pareto estimates consists in constructing procedures that allow us to narrow the Pareto set to a single alternative.

Given estimates on the basis of criteria presented in different scales, it is necessary to make a transition to the resulting scale, namely: from quantitative and qualitative scales to the resulting qualitative scale or, conversely, to quantitative scales. Generalized object assessments in accordance with the methodology of multicriteria evaluation are constructed using the estimating transformation f_Σ such that:

$$f_\Sigma : \left(x_1^{(l)}, x_2^{(l)}, \ldots, x_{n_F}^{(l)} \right) \rightarrow y_\Sigma^{(l)} \in \mathbf{R}^1, \tag{3.3}$$

where $f_\Sigma^{(m)} = M\left(S_{\grave{e}\tilde{n}\tilde{o}}, S_{\eth\mathring{a}\c{c}}\right)[ID(W(F)); A]$—is the function of evaluating objects of set A in a hierarchical tree $ID(W, F)$ with weights of importance W upon a set of criteria F by an aggregation mechanism $M\left(S_{\grave{e}\tilde{n}\tilde{o}}, S_{\eth\mathring{a}\c{c}}\right)$, that depends on the initial S_{in} scale and the resulting $S_{\eth\mathring{a}\c{c}}$ measurement scale;

$y_\Sigma^{(l)}$—a generalized evaluation $a_l \in A$ of the object in the resulting scale $S_{\eth\mathring{a}\c{c}}$.

As an aggregating mechanism f_Σ with known global weighted coefficients of the importance of the end criteria $W = \left\{ wg\left(f_j\right) \right\}_{j=1}^{n_F}$ additive convolution is commonly used

$$y_{\Sigma}^{(l)} = \sum_{j=1}^{n_F} wg(f_j) y_j^{(l)}, \tag{3.4}$$

where $y_l^{(l)} = g(f_j(a_l))$—an assessment $a_l \in A$ of the object in the resulting scale $S_{\eth \mathring{a} \c{c}}$.

The result of the calculation by formula (3.4) can also be represented in the form of an ordered set of alternatives a_l from the set A of objects:

$$a_{l_1} \overset{\pi}{\succeq} a_{l_2} \overset{\pi}{\succeq} \ldots \overset{\pi}{\succeq} a_{n_A} \Leftrightarrow y_{\Sigma}^{(l_1)} \geq y_{\Sigma}^{(l_2)} \geq \ldots \geq y_{\Sigma}^{(l_{n_A})},$$

where n_A—a number of objects from set A.

Let us consider the development of multilevel hierarchical structure of the products competitiveness indicators using an example of objects from the set $A = \{a_1, \ldots, a_l, \ldots, a_{n_A}\}$, where $n_A = 6$. The task of developing a multi-level hierarchical structure in the form of a tree or a network structure of criteria for assessing the quality and effectiveness of the research objects is assigned to experts (analysts) in the subject area.

The description of the hierarchical relationship of indices in the form of a tree is usually carried out by expert methods based on its content or on the basis of decomposition and composition principles.

The decomposition approach is based on the analysis of the semantic content of the global indicator for the sequential definition and structuring of its specific indicators that can be used as criteria in the future. The compositional approach consists in that the list of indicators is first determined, and then, proceeding from the semantic content, they are consistently combined into groups that form more complex indicators. At the same time, the initial list of indicators is updated depending on the completeness of the group with missing indicators.

Let us group together four indicators that characterize the effectiveness of corporations, namely: revenue per employee in dollars; income per employee in dollars; coefficient of return on investment (ROI) in percent; coefficient of investment in the development of competencies and training of staff for sales in percent, and present them as a hierarchical tree of criteria, ranked in descending order of importance (Fig. 3.7).

The requirements for the task of the expert procedure for evaluating and forming local and global coefficients of the importance criteria are as follows:

- The consistency of the importance coefficients with the priority of the criteria according to their importance at any level of the hierarchical tree, i.e. the ordering of the criteria should be preserved in accordance with their qualitative importance;
- The identity of the global coefficients of importance (end) criteria to the normalized values of importance, provided that expert estimates of the degrees of preference in the importance of adjacent criteria reflect the measurability of the criteria in the relationship scale.

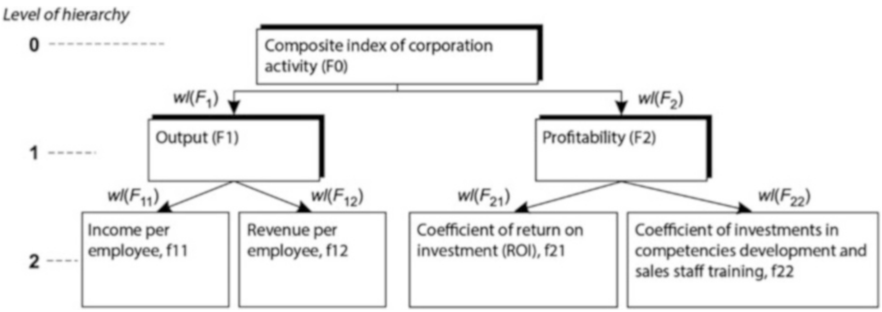

Fig. 3.7 The hierarchical tree of corporate performance indicators: F_0—composite index of the corporation operations (root vertex), F_1—group indicators characterizing the development of a corporation, f_{11}—income per employee in dollars, f_{12}—revenue per employee in dollars, F_2—group indicator characterizing the profitability of a corporation, f_{21}—coefficient of return on investment (ROI) in percent; coefficient, f_{22}—coefficient of investments in the competencies development and sales staff training in percent. Source: Compiled by the authors

The method of forming criteria weights on the basis of product rules for aggregating object estimates is the inverse of the procedure of direct comparison of the superiority of one criterion relative to another and is based on a comparison of vector object estimates. At the same time, there is an adequacy of the aggregation results obtained by additive and production aggregation methods.

The method of approximation of the matrix of pair comparisons of objects by a multiplicative matrix allows us to find the optimal coefficients for the importance of objects (indices) by the criterion of the minimum distance between the normalized elements of the original matrix of pairwise comparison and the multiplicative matrix. The elements of the multiplicative matrix are the solution to the optimization problem. The optimal solution within this method allows estimating the magnitude of the solution obtained by the analytical hierarchy method by T. Saaty.

The result of this stage is the local and global coefficients of importance criteria at each level of the hierarchy. For a hierarchical tree of corporate performance indicators, let the local and global weights be:

– or the group criteria in the root vertex F_0, f local weights: $wl(F_1) = 0.60$; $wl(F_2) = 0.40$;
– for end criteria the local weights:

$$F_1 : wl(f_{11}) = 0.65; \quad wl(f_{12}) = 0.35;$$
$$F_2 : wl(f_{21}) = 0.50; \quad wl(f_{22}) = 0.50;$$

– for end criteria the global weights:

$$F_1 : wg(f_{11}) = 0.39; \quad wg(f_{12}) = 0.21;$$
$$F_2 : wl(f_{21}) = 0.20; \quad wl(f_{22}) = 0.20;$$

Let us renumber the global weights of the end criteria in order in the form $wg_1 = wg(f_{11})$, $wg_2 = wg(f_{12})$, $wg_3 = wg(f_{21})$, $wg_4 = wg(f_{22})$, it is easy to see that the sum of the global weights is 1.

Measuring objects in the original scales at the end vertices of the hierarchical tree of ordered criteria is as follows. Ordinal scales can be used as initial scales for measuring objects by various indicators, if the evaluation is carried out by experts, and quantitative scales, when it comes to statistical data or data obtained with instruments. In general, both the methods of instrumental and expert evaluation and methods of the general theory of statistics can be used to measure the properties of objects. The result of this stage is the evaluation of objects in the initial (qualitative, quantitative) scales by private indicators. The construction of resulting scales and evaluation of objects at different levels of the hierarchical tree of ordered criteria is carried out as follows. In order for the criteria in the construction of generalized object estimates to meet the requirement of homogeneity, i.e. had a common scale, each gradation of which reflected the same level of preference for each evaluated object, it is necessary to go to the resulting canonical point or standardized scale.

Companies' scores on the initial scales are given in Table 3.2.

The transition from the initial quantitative and qualitative relation scales to the resulting canonical (point or standardized quantitative) scales can be carried out by various methods, namely:

– Method of gradation alignment and object assessment adjustment in the initial scale on the basis of acceptable transformations;
– Method of decreasing the number of grades in the order scale;
– Method of transition from continuous and order scales to resulting canonical continuous and discrete scales;
– Method of constructing resulting scales with due account for statistical partition of objects in the initial scale and actor's preferences.

Table 3.2 Initial scores of company performance

Company	F_0—generalized indicator			
	F_1—output		F_0—profitability	
	$x_{11}^{(l)} = f_{11}(a_l)$—revenue per employee in dollars, IV quarter	$x_{12}^{(l)} = f_{12}(a_l)$—earnings per employee in dollars, IV quarter	$x_{21}^{(l)} = f_{21}(a_l)$—coefficient of return on investment (ROI) in percent	$x_{22}^{(l)} = f_{22}(a_l)$—coefficient of investment in the competencies development and sales staff training in percent
a_1	26,381	401,398	12.21	3.0
a_2	25,482	505,705	10.44	2.8
a_3	31,271	373,737	9.68	2.5
a_4	29,528	349,646	9.65	2.5
a_5	3649	14,089	0.5	0.25
a_6	12,235	17,868	0.5	0.5

Note: $x_{ij}^{(l)} = f_{ij}(a_l)$—object evaluation $a_l l = \overline{1,\ 6}$, in the initial scale, $\left(i = 1,\ 2;\ j = \overline{1,\ 4}\right)$

Source: Compiled by the authors

The result of this stage is the evaluation of objects in the resulting equivalence scales by individual indicators.

Since the objects scores were presented in the initial different scales: in the quantitative ratio and the difference scales and in the order 10-point scale, then let us take a 100-point scale a resultant uniform scale. The transition from a quantitative ratio scale to an ordinal point scale is to be carried out using a multi-point map:

$$g\colon \left[f_{*j} + (r-1)h_j, f_{*j} + rh_j\right] \to r,$$

where $X^{(0)}_{j,\ r} = \left[x_{j,\ r-1}, x_{j,\ r}\right]$; $x_{j,\ r-1} = f_{*j} + (r-1)h_j$; $x_{j,\ r} = f_{*j} + rh_j$;

$r \in X^{(1)}_j = \{1,\ 2, \ldots, m\}$ gradation of the resulting ordinal (point) scale;

$h_j = \dfrac{f^*_j - f_{*j}}{m}$—uniform spacing of f_j criteria in a quantitative continuous scale;

f^*_j—the maximum value f_j of the criterion when measuring $a_l \in A$ an object;

f_{*j}—the minimum value f_j of the criterion when measuring $a_l \in A$ an object;

m—is the number of intervals $\left[f_{*j},\ f^*_j\right]$ in partition f_j of the range of criteria values, which coincides with the number of scale gradations in the ordinal point scale.

Figure 3.8 shows the transition from the continuous scale to the resulting ordinal one with a fixed uniform spacing of the initial scale h_j.

The result of transition to the resulting scale is given in Table 3.3, where $y^{(l)}_{ij} = g_{ij}(a_l)$ —the assessment of the object $a_l = \overline{1,\ 6}$, in the resulting scale, $\left(i = 1,\ 2;\ j = \overline{1,\ 4}\right)$.

Then we can proceed to generlizing the objects valuations through various mechanisms of aggregating the hierarchical structure of the criteria.

Aggregating the evaluations by a global criterion is usually performed by several aggregation mechanisms depending on the initial data: the integral mechanism of aggregating object estimates in the resulting scale with and without importance criteria weights.

After singling out the single variant of solving the metatask of multicriterial evaluation (Table 3.3) the recommendations for decision making is worked out.

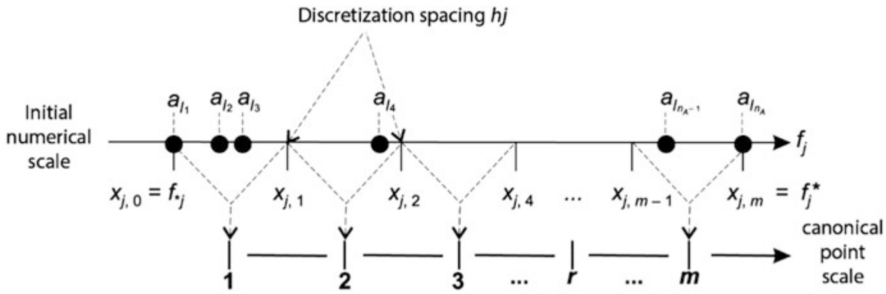

Fig. 3.8 Transition from the continuous scale of f_j criterion to the resulting ordinal one with a uniform spacing of the initial scale. Source: Compiled by the authors

Table 3.3 Evaluation of companies according to the resulting scale

Company	F_0—generalized indicator			
	F_1—output		F_1—profitability	
	$y_{11}^{(l)} = g_{11}(a_l)$—revenue per employee in dollars, IV quarter	$y_{12}^{(l)} = g_{12}(a_l)$—earnings per employee in dollars, IV quarter	$y_{21}^{(l)} = g_{21}(a_l)$—coefficient of return on investment (ROI) in percent	$y_{22}^{(l)} = g_{22}(a_l)$—coefficient of investment in the competencies development and sales staff training in percent
a_1	9	8	10	10
a_2	8	10	9	10
a_3	10	8	8	9
a_4	10	7	8	9
a_5	1	1	1	1
a_6	4	1	1	1

Source: Compiled by the authors

Table 3.4 The results of meta-aggregating and comparing the effectiveness of utilizing company's human capital

Company	Rating position					
	Integral mechanism		Local mechanism with weights		Meta-aggregating	
	Without weights	With weights	Aggregated score	On the 10-point scale	Position	Ranking
a_1	5.5	6	5.5	4.5	1	6
a_2	5.5	4	5.5	4.5	2	5
a_3	4	5	3.5	4.5	3	4
a_4	3	3	3.5	4.5	4	3
a_5	1	1	1	1	6	1
a_6	2	2	2	2	5	2

Source: Compiled by the authors

According to the results of metaggregation of data in the ranking scale of Table 3.4 we have the following ranking chain:

$$a_1 \succ a_2 \succ a_3 \succ a_4 \succ a_6 \succ a_5.$$

Comparison of objects by preferability, as far as one object is more preferred than another, is possible not only according to a 10-point scale, but also to any other. However, it is more convenient to compare on the 100-point scale, which is usually used in economic research.

The practical application of the presented methods of the rating evaluation is connected to the fact that investments in human capital at enterprises and corporations of high-tech sectors are part of the decisions by their management on the allocation of limited resources that these enterprises or corporations possess at a particular moment in time, i.e. determining the priorities for their use. These priorities influence not only the current productivity of an enterprise but also its development in the long term.

Here we can witness three interrelated problems:

1. The intensity of the resources use for the development of staff competencies;
2. Proportionate distribution of these resources within the organization;
3. Workforce structure.

Data concerning the impact of the intensity of the use of these resources on enterprise performance and the rational level of costs attach a growing importance to investments in the development of competencies and training of personnel that is defined as "intellectual investments". However, in terms of costs and benefits, the effectiveness of these investments is within certain limits, where "more" does not always mean "better": a low level of investment can reduce costs, but this will worsen staff competencies and slow the development of the enterprise in the long term; at the same time, too high level will overload the enterprise, sharply reducing the profitability ratio due to a decrease in the return on investment in the development of competencies. The key indicator here is the ratio of investment in the development of competencies and training to measurable criteria of the main activities of enterprises and corporations in high-technology industrial sectors.

The proposed model can be used to assess the effectiveness of competence and innovation management centers, as well as to justify the most promising areas of knowledge sharing between enterprises of the corporation. This model can be integrated into the decision-making system to start and allocate funding for projects to develop certain new competencies and is built into the IT knowledge management system. In addition, this model can be used as a benchmarking tool, i.e. comparison of the capabilities of the evaluated enterprise with competitors. Finally, the model can be used as a tool to assess the impact of increasing aggregate investment in human capital on the company's competitiveness.

Moreover, a high level of human capital indicates the availability of appropriate organizational competencies to manage it. The multi-factor nature of the proposed model of measuring human capital allows assessing the contribution to the overall result of influencing factors, and the comparison of factors for different enterprises allow to identifying the leader.

Thus, the model enables the company to solve several tasks in the field of competence management:

– To assess the overall development of human capital as an integral criterion of competency in the field of HR and knowledge management;
– To identify the strengths of the organization and the risks associated with managing human capital. Factors included in the model can be considered as resources that ensure the achievement of high results, which corresponds to the "resource theory" of the organization's activities;
– To compare objective quantitative indicators according to competitors and to identify those core competencies and their bearers, whose impact on competitiveness is the most critical and important.

This model is of particular relevance for organizations and departments entirely engaged in the development of new breakthrough competencies, in which their key performance indicators are based on this. In the modern environment, the assessment of the effectiveness of competency and innovation management centers and the choice of the most promising areas for knowledge sharing (transfer of technologies and competencies) are becoming one of the tools to increase the competitive advantages of high-tech corporations. Competency and innovation management centers and centers for creating and transferring technologies are often costly units. In the context of crisis and financing decrease, such units are the first candidates for reduction and disbanding, and their managers, as well as the most far-sighted managers of the corporate center, are compelled to defend their activities and justify it. In the context of the lack of quantitative methods, this model can become the methodological basis for assessing the performance of a competency and innovation management center and its impact on competitiveness, even if it is only a cost center. Therefore, when establishing a new competency and innovation management center or a network of such centers, it is recommended to adapt this model to their specificity and through it to assess the impact of the activities of a certain center on the overall competitiveness of the enterprise.

Based on the tools described in this chapter, we can build a system of forming competitive advantages based on the application of competencies, which is presented in a diagram in Fig. 3.9.

This system encloses a calculation and evaluation module. Within the framework of this module, the assessment and ranking of core competencies should be conducted, including the justification their influence on the overall competitiveness of the enterprise.

In Fig. 3.8 demonstrates that the competitive advantages management tool includes models of assessing and ranking core competencies for their use in managing the competitiveness of high-tech corporations, models of assessing the competitiveness of the company, taking into account competitive advantages generated from core competencies, as well as multi-criteria rating assessments of the effectiveness of the human capital utilizing at corporations as a source of organizational competencies.

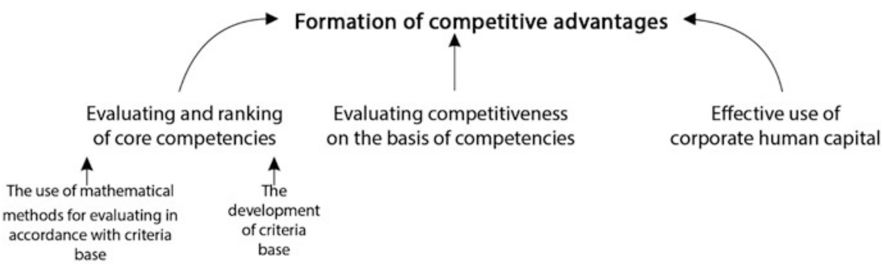

Fig. 3.9 The system of forming competitive advantages of high-tech corporations based on the competencies. Source: Compiled by the authors

Each of these models solves the particular task of managing competitiveness. Thus, the assessment and ranking of competencies allows identifying core competencies and directing them to those industries where they can most enhance competitiveness on the basis of a significant contribution to the dignity of end-products perceived by consumers or the creation of other products and services, including those based on new physical principles. The effective application of core competencies directly affects the access of competency holders to a variety of different product and service markets.

The competitiveness evaluation of a corporation on the basis of competencies allows simulating the chain of "competency-innovation-competitiveness" and evaluating the effectiveness of forming new competitive advantages quantitatively.

The effectiveness evaluation of the of use of the human capital utilizing by corporations as a source of organizational competencies is the basis for choosing the area of using competency and innovation management centers in order to determine which area will lead to the greatest growth of the corporation competitiveness.

At the same time, innovative technologies are used in the production of science-intensive products, which influence the competitiveness of end products. Due to the venture nature of the technology business, especially with the application of technologies and approaches based on new physical principles, various external and internal risks can arise, which often entail financial losses and rise in price of end products, which also affects the changes in competitiveness indicators. These risks must be quantified and digitized. In this regard, it becomes necessary to develop tools that allow taking into account the influence of these factors on the competitiveness of high-tech corporations in the context of competency and innovation centers.

A promising step in the medium term can be the generalization of the developed models influence on the scale of the entire industry that would consider the development of the human capital of the industry as a whole, the core competencies and industries required for the industry, the costs of creating them (taking into account the synergetic effect of cooperation), comparison with other industries for a number of key features.

Also the most important task is the development of a standardized system of indicators for a high-tech industry that would reflect the level of competencies development and costs for each enterprise in the industry and for all enterprises in general. Without solving this problem, full-scale modeling is possible only at the level of individual enterprises and divisions.

An important task is the integration of these models into management software, and a more priority task may be the approbation of these models in a pilot enterprise or the competency and innovation management center.

Another task in this area is the integration of this group of models into the intellectual property and competency assessment system adopted by technology transfer centers possessing international level and scope, since at present management is increasingly characterized by a desire to capitalize competencies (including through the possible selling them in the international market), as well as ensuring their positive impact on the value (market capitalization) of the company.

The result of the implementing the entire complex of described models should be the integration of individual competencies of enterprises into a single international sectoral inforsphere for technology transfer, the growth of technological leadership of knowledge-intensive enterprises through monitoring the effectiveness of costs for targeted development of competencies.

Chapter 4
Management of Competitive Advantages of a Corporation Based on Economic-Mathematical Modeling

4.1 Managing the Competitive Advantages of a High-Tech Corporation on the Basis of Core Competencies Assessing and Ranking

Studies conducted in the previous chapter have shown that the competitiveness of high-tech corporations abroad is achieved through the establishment of systems for integrating fundamental and academic science with the industrial sector. This allows to generate new competencies and to systematize them with the means of specialized intra-corporate information platforms for exchange and management of competencies.

In the case of large holding structures, such intra-corporate platforms form a network of competencies-and-innovation management centres that unite data across the entire range of corporate competencies.

In this case, in order to increase the efficiency of corporate competitive advantages management, there is a question of allocating core competencies and ranking them according to the degree of significance in the organization's activities, since it is core competencies that can form the basis of breakthrough innovations and the source of new standards both in a single industry and in several industries. They provide the holder with global dominance or global competitiveness, as well as the potential to maintain the market leadership of the products and services that are being created. Core competencies (CC) have a number of characteristic features:

– They provide potential access to many different markets of products and services;
– They make a significant contribution to consumer-perceived advantages of end products;
– They are quite non-trivial to be imitated by competing companies or groups.

As a rule, core competence can be represented at several levels of positioning, from a narrow industrial to a global multidisciplinary one. The levels of competencies positioning are illustrated in Fig. 4.1.

A. Chursin, A. Tyulin, *Competence Management and Competitive Product Development*, https://doi.org/10.1007/978-3-319-75085-9_4

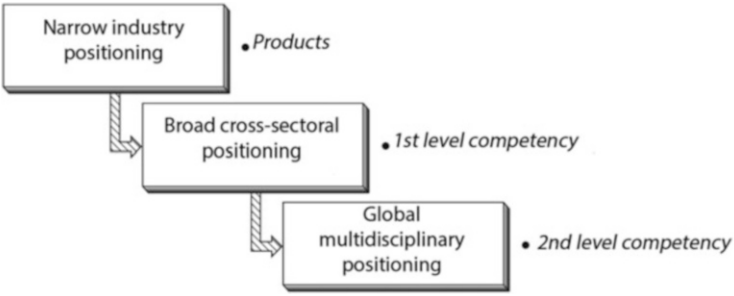

Fig. 4.1 CC positioning levels. Source: Compiled by the authors

The core competencies of the organization at different levels of positioning are the key to its competitiveness and to the development of competitive advantages, both temporary and sustainable.

Temporary factors are understood to mean favorable factors in the external environment. Under certain conditions, temporary factors can transform into sustainable ones. A certain level of risk may correspond to temporary factors, presenting some danger for the preservation of unique technological competencies in the long term. An example of such a risk factor may be the aging of staff—those holders and creators of competencies, coupled with insufficiently effective transfer of knowledge and skills to young professionals.

The study of sustainable and temporary factors, together with possible risks, can be carried out using both a simple description and standard analysis tools. An example of such a tool is SWOT analysis, which results in a matrix of a certain type that reflects various factual material about core competencies.

Another stage in the core competencies analysis may be their research in terms of industry positioning. This analysis allows assessing competencies both in terms of the consumer properties of a product and in terms of finding opportunities for the application of competencies in other industries.

To identify the possibility of extending a competency to the broad cross-sectoral positioning level, one can use the approach of presenting production at the narrow industry positioning level as a business process. This creates an opportunity to form the structure of business processes and will help to identify those that provide a global advantage or global competitiveness of the products.

Then it is necessary to identify those resources that determine unique product properties for a certain industry and which are intended to provide a global advantage or competitiveness at other positioning levels. At this stage, new strategic opportunities can be analyzed, and a database of unique approaches and techniques applicable in other industries can be created.

Another step in the CC qualitative assessment can be the preparation of various forecasts and making certain assumptions on extending the CC to the cross-sectoral and multi-disciplinary positioning levels.

The core competencies assessment scheme can be presented as follows (Fig. 4.2).

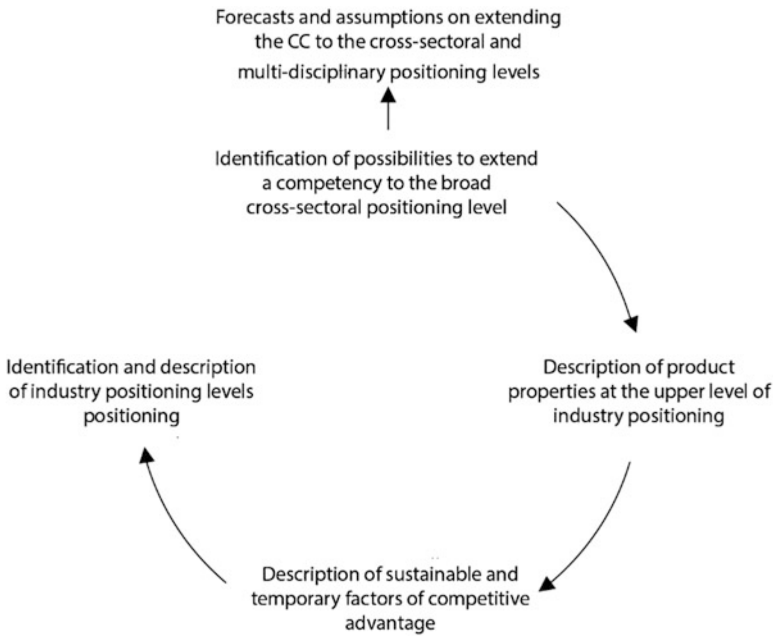

Fig. 4.2 CC assessment scheme. Source: Compiled by the authors

Based on the results of the assessment, competence can be attributed to a group providing global superiority or global competitiveness.

The methodological approach to quantify and rank core competencies involves obtaining an aggregate value (index) that characterizes the value and importance of a competency based on characteristics identified in accordance with the developed format for describing core competencies. Ranking of key competencies is determined by their comparison based on the calculated estimates.

Thus, to obtain an aggregated estimate, it is necessary to quantify each characteristic. This is achieved through development of a methodology with the use of expert judgment.

The high-tech industries have a lot of core competencies. In this regard, a comprehensive analysis for each competency of each enterprises or group within a high-tech industry is a complex and time-consuming task involving a large number of experts and processing a large number of personal data.

The methodology describes three stages (Fig. 4.3) to quantify core competencies and to perform ranking on its basis:

– Quantifying the core competencies for which expanded questionnaires were completed (the form of expanded questionnaires is presented in Appendix). Such competencies call reference competencies;

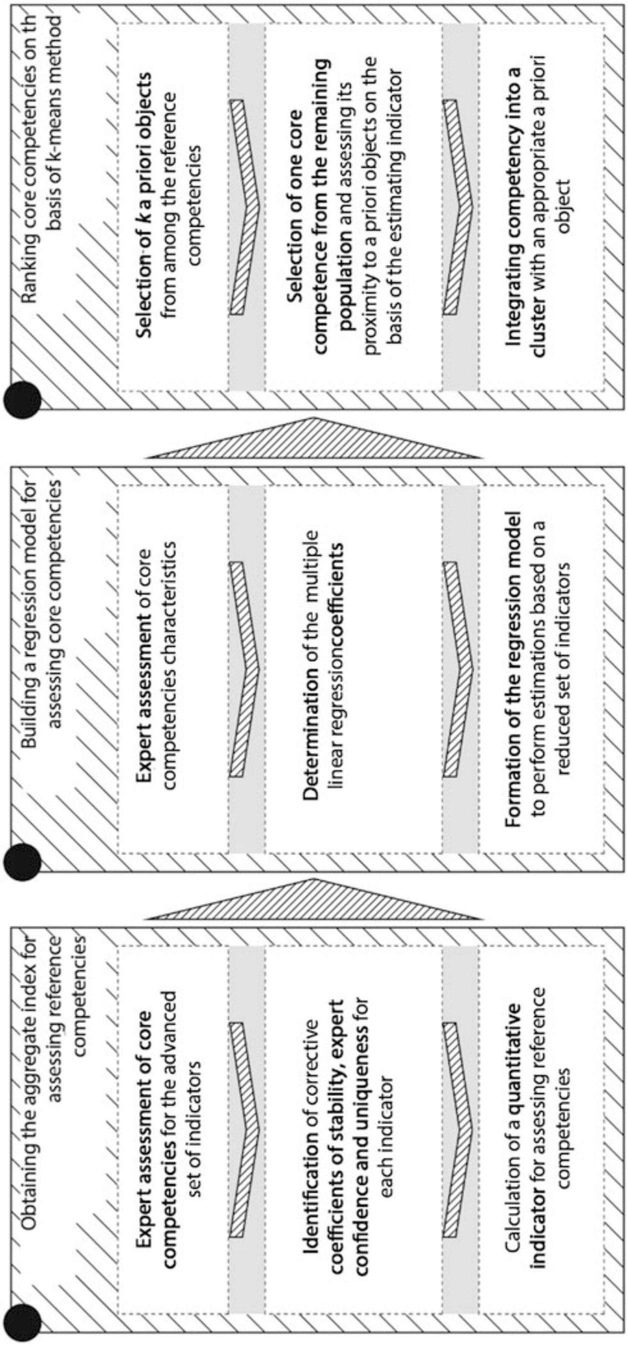

Fig. 4.3 Stages of the methodology for core competencies assessing and ranking implementation

- Building a regression economic-mathematical model based on the results of assessing the reference competencies for obtaining core competencies evaluations on a short questionnaire;
- Evaluating the core competencies on the basis of the regression model and their subsequent ranking based on the evaluation results.

The implementation of the assessing and ranking core competencies methodology involves embedding it in an information and analytical system that uses algorithms for assessing reference competencies, methods for determining the parameters of the regression model, tools for expert decisions making support and visualization of the results.

Expert assessments of the following characteristics are the basic initial data for the quantification of core competencies P_1, P_2, ..., P_9:

- Competent staff armed with advanced research toolkit and a modern production base;
- Functional environment for research and production activities;
- The degree of maturity of the technologies developed through the competency under consideration;
- The ability to extend core competencies to other industries;
- Competitors—carriers of similar core competencies;
- If there are competitors, advantages or disadvantages to them;
- Academic school with a core competency-related research;
- Licenses, certificates, awards (primarily of international recognition);
- The prospect of maintaining core competencies in the medium and long term.

Describe the stages of the methodology:

Stage 1. Assessment of reference core competencies The task of assessing the reference competencies is to build an aggregated evaluation indicator based on the existing expert description of the core competencies. Denote this indicator *EK*. Each core competence is defined by a set of characteristics:

$$P = \begin{pmatrix} P_1 \\ P_2 \\ \dots \\ P_N \end{pmatrix}.$$

The value of the *EK* indicator depends on the characteristics of the core competencies P_1, P_2, ..., P_N, that is

$$EK = EK(P_1, P_2, \dots, P_N).$$

The values of the indicator belong to the interval [0; 1], that is

$$EK \in [0;1].$$

The greater value of the indicator shows the greater value and uniqueness of the core competency, and therefore, its greater potential rank among the competencies compared.

The aggregated value of a core competency is the sum of weighted parameters which depend on characteristics of the competency:

$$F = \begin{pmatrix} F_1(P_1) \\ F_2(P_2) \\ \dots \\ F_N(P_N) \end{pmatrix},$$

that is

$$EK = \sum_{i=1}^{N} (w_i \cdot F_i(P_i)),$$

where w_i are the weights that match the ratio:

$$\sum_{i=1}^{N} w_i = 1.$$

Weights reflect the relative contribution of the relevant parameters of core competencies to the overall assessment *EK*. Vector of weight coefficients

$$W = \begin{pmatrix} w_1 \\ w_2 \\ \dots \\ w_N \end{pmatrix},$$

is subject to expert assessment. In the questionnaire, the respondent issues a rating on the scale $L' = \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}$. Then the rating estimates are normalized to the sum of all estimates, resulting in a vector of values. Its components give a total of 1. This is the vector of weighting coefficients.

Next, let’s take a look at an assessment of core competency features. The most effective and simple way is realized by assigning values on a scale to qualitative characteristics. Typically, such scales establish a correspondence between objects on the principle “less–more”, “less insignificant–more important”, “better–worse”, etc. In accordance with the principle of obtaining an aggregated value *EK*, within the framework of the described model it is convenient to use numerical values in the interval [0;1] for transforming the qualitative characteristics of core competencies into numerical ones. In most cases, it will suffice to use the following set of L-points to construct the scale:

$$L = \{0; 0,1; 0,2; 0,3; 0,4; 0,5; 0,6; 0,7; 0,8; 0,9; 1\}.$$

In practice, it is convenient to make such assessments using the scale

$$L' = \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}.$$

A core competency questionnaire supposes the use of exactly such a scale.

Conversion of values from the scale L' into values of the scale L is carried out by dividing the corresponding numerical values by 10.

The assessment procedure should be conducted for each characteristic of core competencies. As a result, an estimate from the interval [0;1] will correspond to a characteristic:

$$P_i \to l^i \in [0; 1].$$

Next, consider the formation of a core competency assessment indicator *EK*.

The functions of the core competencies characteristics can be represented in the form of power dependencies:

$$F_i(P_i) = M_i(l_i - \alpha_i)^{\gamma_i}, \quad i = 1, 2, \ldots, N$$
$$F_i(P_i) = 0, \quad (l_i - \alpha_i) < 0.$$

So, the value l_i is an estimate of the corresponding characteristic according to the introduced scale l:

$$0 \le l_i \le 1.$$

The value M_i is called the stability coefficient of the characteristic and expresses the risk of competence withdrawal (from the set of CC), associated with this characteristic:

$$0 \le M_i \le 1.$$

In this sense, the stability coefficient of the characteristic depends on the risk of rating decrease. The expert shall rate each characteristic of a CC in the questionnaire with a value from the interval [0; 1]. The larger estimated value corresponds to its greater stability.

The next component of *EK* is the coefficients α_i, that must satisfy the conditions

$$0 \leq \alpha_i \leq 1, \quad i = 1, 2, \ldots, N.$$

The rationale for these coefficients is the marginal evaluation of the characteristic under consideration. If the coefficient has a value other than 0, then the project has a so-called possible underestimation because of the lack of information about the characteristic under consideration. In the questionnaire, a respondent gives an estimate for each CC characteristic from the interval [0; 1]. The zero value of the parameter corresponds to the absence of doubt in the respondent when rating the characteristics.

The γ_i value (exponent) in the CC assessment formula is called the unique innovation indicator. This indicator can take values from the interval [0; 1]. The economic meaning of this indicator lies in the extent to which the characteristic in question corresponds to the concept of a unique innovation characteristic. The expert shall rate each characteristic of a CC in the questionnaire with a value from the interval [0; 1].

Thus, different degree of attribution to unique innovations can be observed for different CC characteristics.

According to the proposed model, an assessment of the reference competencies is conducted and a final protocol of a competencies assessment is drawn up. It includes CC characteristics assessments on the proposed scale and the final value of *EK* indicators.

So the final formula for*EK* takes the following form:

$$EK = \sum_{i=1}^{N} \left(w_i \cdot M_i (l_i - \alpha_i)^{\gamma_i} \right),$$

where N is the number of CC characteristics.

Stage 2: Build a regression model of CC assessment CC assessment according to the scheme proposed at the previous stage is laborious and requires a lot of work of a respondent to fill in the questionnaires. In practice, such an approach is not always possible. In this regard, there is a need for a simpler tool to assess core competencies. The solution is the multiple regression model.

The initial data for building the model will be the evaluations of CC characteristics on the scale proposed at the previous stage and values of *EK* estimated using the method of the previous stage.

Now, let us analyze m reference competencies:

$$K = \begin{pmatrix} K_1 \\ K_2 \\ \cdots \\ K_m \end{pmatrix}.$$

The analysis results in matrix L of the obtained at the previous stage expert estimates of the parameters l, describing the core competencies:

$$L = \begin{pmatrix} l_{11} & l_{12} & \cdots & l_{1N} \\ l_{21} & l_{22} & \cdots & l_{2N} \\ \cdots & \cdots & \cdots & \cdots \\ l_{m1} & l_{m2} & \cdots & l_{mN} \end{pmatrix}.$$

The regression model also requires the EK—estimates of the reference competencies:

$$EK = \begin{pmatrix} EK_1 \\ EK_2 \\ \cdots \\ EK_m \end{pmatrix}.$$

Thus, we can make the following system of equations based on the results of the measurements:

$$\begin{cases} EK_1 = b_0 + b_1 L_{1,1} + b_2 L_{2,1} + \cdots + b_m L_{m,1} + \varepsilon_1, \\ EK_2 = b_0 + b_1 L_{1,2} + b_2 L_{2,2} + \cdots + b_m L_{m,2} + \varepsilon_2, \\ \cdots \\ EK_N = b_0 + b_1 L_{1,\mathrm{N}} + b_2 L_{2,\mathrm{N}} + \cdots + b_m L_{m,\mathrm{N}} + \varepsilon_N. \end{cases},$$

where b_i are the coefficients of multiple regression;

ε is a vector of random deviations.

Regression coefficients reflect the relative contribution of each CC characteristic to the overall assessment.

The estimation of regression coefficients is performed by one of the standard methods (for example, the least squares method). These methods are realized in special mathematical software (Maple, Excel), and can also be easily programmed using high-level languages.

It is also necessary to test the model for adequacy by calculating the variance of the errors.

The average approximation error should not exceed 10–12%.

The result of calculating the regression coefficients is the equation of regression. Based on this equation and the CC characteristics one can obtain EK estimates:

$$EK = b_0 + b_1 L_1 + b_2 L_2 + \cdots + b_m L_m.$$

Thus, the assessment of CC characteristics is based on expert assessments of CC characteristics and the regression model.

The use of the proposed multiple regression model makes obtaining core competency estimates much simpler: the data of the short questionnaires that suppose evaluating only the CC characteristics P_1, ..., P_9 becomes sufficient to obtain estimates.

Stage 3: Core competencies ranking Core competencies can be ranked based on the received assessments. The rank of competence will correspond to its value and uniqueness in the range of competencies considered.

The obvious way to rank core competencies is to determine the rank based on the values of *EK*. Greater rank corresponds to a greater value of *EK*.

Another way to rank core competencies is clustering with the use of k-means method. When using this approach to clustering, some initial conditions are established. Limitation of number of clusters, preliminary assignment of centers and radii of clusters can be such conditions. Describe the application of the *k*-means method to clustering the core competencies. We select reference competencies as centers of clusters.

Let us consider the k-means clustering algorithm in detail. Let us consider *N* core competencies and split them into clusters according to their values and uniqueness. We consider the proximity to the reference competencies values the optimality criterion.

Let core competencies be split into *k* clusters. k a priori objects are selected from among the full set of N core competencies at the beginning of clustering operation. Then we need to select one of them from the remaining set $(N - k)$ and check which of the a priori objects it is closest to. The proximity of the two core competencies we assess as the Euclidean distance between the respective values of *EK*. This competence is combined into one cluster with the corresponding a priori object. A new a priori object is computed to become the center of a new cluster. After $(N - k)$ steps all core competences are assigned to one of the clusters.

All core competencies are again added in turn to the already formed clusters in order to obtain a sustainable partitioning. If a partition obtained similar to the previous one, algorithm is terminated; if not, the iterative procedure continues. This iterative algorithm minimizes variance within clusters.

Thus, k clusters are formed whose competence rank corresponds to the place of this cluster's a priori object estimate in the series of all a priori estimates.

Application of the proposed approach to the description and ranking of the organization's competencies allows achieving the strategic goals and implementing the priority innovations that contribute to improving the competitiveness of products and the organization as a whole.

4.2 Model for Assessing the Impact of Key Competencies on the Competitiveness of High-Tech Organizations

Assessment of competitiveness is one of the most important economic tasks of knowledge-based organizations strategic management. Various mathematical methods are used to quantify the competitiveness of organizations that allow one to study the influence of various economic factors on the dynamics of the competitiveness. Improving the competitiveness is always based on the desire to obtain additional competitive advantages. In case of high-tech and knowledge-based enterprises, competitive advantages arise due to emergence of new core competencies.

Consider the author's mathematical model of a quantitative estimation of organizations competitiveness based on the competitive advantages arising as a result of a competence emergence. The competitiveness will be assessed using the vector of numeric indicators. We will consider N numerical indicators of the competitiveness of organizations, which we denote by Qi. These indicators will combine into the vector of competitiveness (4.1):

$$Q(t) = \begin{pmatrix} Q_1(t) \\ Q_2(t) \\ \vdots \\ Q_N(t) \end{pmatrix}. \tag{4.1}$$

Since we will consider the problem of assessing competitiveness taking into account the dynamic factors associated with the emergence of new competitive advantages arising from the acquisition of relevant competencies by organizations, then we consider the competitiveness indicators as time-dependent. It is appropriate to apply the apparatus of differential equations in mathematical models describing dynamic processes in the economy. The use of differential equations implies that the considered model is continuous. This mathematical abstraction is valid in this case, since the knowledge-based organizations competitiveness develops on large time intervals.

The basic dynamic equation (4.2) can be written in the following form:

$$\frac{dQ(t)}{dt} = F(t, Q(t), G(t, Q(t))). \tag{4.2}$$

This formula uses the G function to reflect the influence of external and internal factors on the dynamics of competitiveness. In particular, the impact of competencies on the organization's activities will be taken into account through the formalism of this function. We will consider concrete realizations of the basic dynamic differential equation.

It is well known that dynamic models describing the behavior of competitiveness indicators are subject to natural diffusion. This diffusion leads to the fact that in the absence of external factors, numerical indicators have a constant tendency to decrease. Mathematical interpretation of this phenomenon is expressed as follows:

$$\frac{dQ(t)}{dt} = A(t)Q(t) + G(t, Q(t)).$$

In this formula $A(t)$ is the $N \times N$ square matrix with variable elements. In order for the equation in question to possess the property of diffusion of competitiveness indicators, the following condition should be satisfied:

$$Re\lambda_i(t) < 0, i = 1, 2, \ldots, N,$$

Where the factors λ are eigenvalues of the matrix $A(t)$.

Since the matrix under consideration is time-depend, its eigenvalues also depend on time. Their absolute values determine the rate of competitiveness indicators decrease in the mathematical model under consideration.

In the simplest cases, matrix $A(t)$ can be considered as the diagonal matrix with its eigenvalues on the main diagonal:

$$A(t) = \begin{pmatrix} \lambda_1(t) & 0 & \cdots & 0 \\ 0 & \lambda_2(t) & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots & \lambda_N(t) \end{pmatrix}.$$

However, full matrices should be used in more complex models. The off-diagonal elements of the matrix reflect the economic fact of mutual dependence between different indicators of competitiveness.

To take into account the influence of the organization's competence on the dynamics of competitiveness let us consider the G function on the right side of differential equation (4.2) in more detail:

$$\frac{dQ(t)}{dt} = A(t)Q(t) + \sum_{k=1}^{M} B_k(t)G_k(t).$$

Here, the use of M competitive advantages to manage the competitiveness of the organization is considered. These competitive advantages are described by vectors:

$$G_k(t) = \begin{pmatrix} g_1^k(t) \\ g_2^k(t) \\ \vdots \\ g_{N_k}^k(t) \end{pmatrix}.$$

In this mathematical model, dimensionless values are used to describe economic processes. This allows concentrating on the functional description of the phenomena under consideration.

Matrices that describe the quantitative impact of competitive advantages on the organization's competitiveness dynamics are denoted by B_k.

$$B_k = \begin{pmatrix} b_{11}^k & b_{12}^k & \cdots & b_{1N_k}^k \\ b_{21}^k & b_{22}^k & \cdots & b_{2N_k}^k \\ \cdots & \cdots & \cdots & \cdots \\ b_{11}^k & b_{11}^k & \cdots & b_{NN_k}^k \end{pmatrix}.$$

Consider a linear differential system that will describe the dynamics of the organization's competitiveness indicators. There is a managed dynamic system. The purpose of managing this system is to improve all competitiveness indicators.

For the mathematical formalism, the objective functional in the form of an integral index of competitiveness can be generated:

$$IQ = \alpha_1 Q_1(T) + \alpha_2 Q_2(T) + \cdots + \alpha_N Q_N(T).$$

Consider the value of the competitiveness indicators for the final time point T. The goal of competitiveness management is high values of competitiveness indicators at the final moment without taking these values into account at intermediate points in time.

To calculate the integral competitiveness index, it is necessary to use weights that satisfy the conditions:

$$\begin{aligned} &\alpha_1 + \alpha_2 + \cdots + \alpha_N = 1 \\ &\alpha_1 \geq 0, \alpha_2 \geq 0, \ \ldots, \alpha_1 \geq 0. \end{aligned}$$

As already noted, the main tool for managing competitiveness in this model is the use of competitive advantages. This competitive advantage is formed due to the core competences development which is the scientific and technical basis that allows developing and implementing innovative technologies that, in turn again, allow creating competitive advantages for increasing the competitiveness of organizations.

Consider a mathematical model for the dependence of competitive advantages on the organizations competencies.

Competences affecting competitive advantages are complexes of different individual competencies. A variety of different competencies should be considered to create significant competitive advantages. The mathematical model for creating competitive advantages due to acquisition of competencies is based on the finite state machines formalism. The finite-machine approach allows considering complex economic processes in which dynamics is described not only by external influences, but also by the internal state of the system.

Let competitive advantages be described by the following finite set:

$$H = \{H_1, H_2, \ldots, H_K\}.$$

Although the basic dynamic equation (4.2) is a differential equation with continuous time, consider in this equation some competitive advantages described by finite sets. This is permissible in the economic model in question.

Competitive advantages result from the use of innovative technologies. Consider a finite set describing the innovative technologies that create competitive advantage. Denote this set as follows:

$$I = \{I_1, I_2, \ldots, I_L\}.$$

Assume that at the initial instant of time the system is in state I_l. This set is changing as a result of the emergence of new competencies. In this model of assessing the competitiveness taking into account the competence of the organization, we will consider the following set of possible competencies:

$$G = \{G_1, G_2, \ldots, G_M\}.$$

The dynamics of the system of competitive advantages, depending on the competences being created, as follows. Let the organization's competitiveness management results in the following sequence of competencies:

$$G_{i_1}, G_{i_2}, \ldots, G_{i_p}, \ldots.$$

Then we get a sequence of innovative technologies:

$$I_{j_1}, I_{j_2}, \ldots, I_{j_p}, \ldots.$$

In addition, innovative technology creates a chain of competitive advantages:

$$H_{k_1}, H_{k_2}, \ldots, H_{k_p}, \ldots.$$

According to the finite-machine model, these sequences are interrelated by the following ratios:

$$\begin{aligned} I_{j_p+1} &= A\left[I_{j_p}, G_{i_p}\right], \\ H_{k_p+1} &= B\left[I_{j_p+1}\right]. \end{aligned} \tag{4.3}$$

Let us use transition functions in these relationships:

$$A : I \times G \to I \text{ and } B : I \to H.$$

Using relations (4.3), we can formally define an economic-mathematical model describing the chain of "*competencies—innovations—competitive advantages*". This chain shows that the influence of competencies on competitive advantages is non-linear. Moreover, this influence can include temporary lag of various kind, since the economic realization of competence in the form of innovative technologies that can bring certain competitive advantages to a knowledge-intensive organization takes a long time.

Consider a controlled dynamic system described by the differential equation:

$$\frac{dQ(t)}{dt} = A(t)Q(t) + B_1(t)\left[H^1(t)\right] + B_2(t)\left[H^2(t)\right] + \cdots + B_M(t)\left[H^M(t)\right].$$

In this equation, the right side indicates impulse functions that reflect the influence of competitive advantages on the dynamics of competitiveness indicators of a knowledge-based organization, taking into account new competencies. These functions are as follows:

$$H^k = \begin{cases} 0, & t < a_k \\ h^k(t), & t \in [a_k, b_k] \\ 0, & t > b_k \end{cases}.$$

Thus, these functions have a finite time interval. The time interval can be quite large for some competitive advantages.

Now, consider the impact of the core competencies on competitive advantages that can have a significant impact on the dynamics of competitiveness indicators. According to the proposed mathematical model for assessing the competitiveness of organizations depending on competitive advantages, the dynamics of indicators is described by a differential equation in which the matrix of diffusion of competitiveness indicators has the major influence. In general, the system as follows:

$$\frac{dQ(t)}{dt} = A(t)Q(t) + G(t, Q(t)).$$

However, the impact of certain key competencies may be considered not only in equations but also in the matrix $A(t)$. Consider the core competencies that lead to obtaining fundamental competitive advantages. Denote this factor by U(t) as a key control. Then in general we obtain the following dynamic equation:

$$\frac{dQ(t)}{dt} = A^{U(t)}(t) + G(t, Q(t)).$$

We will assume the following ratio is fulfilled:

$$A^0(t) = A(t).$$

Here is an example of the influence of $U(t)$ function on the matrix $A(t)$:

$$A^{U(t)} = \begin{pmatrix} a_{11}(t) + u_{11}(t) & a_{12}(t) + u_{12}(t) & \cdots & a_{1N}(t) + u_{1N}(t) \\ a_{21}(t) + u_{21}(t) & a_{22}(t) + u_{22}(t) & \cdots & a_{2N}(t) + u_{2N}(t) \\ \cdots & \cdots & \cdots & \cdots \\ a_{N1}(t) + u_{N1}(t) & a_{N2}(t) + u_{N2}(t) & \cdots & a_{NN}(t) + u_{NN}(t) \end{pmatrix}.$$

If the moment of action of this control is local in time, then a violation of the condition that the diffusion matrix has eigenvalues whose real part is strictly less than 0 becomes possible. The presence of eigenvalues with positive real parts will mean that some competitiveness indicators will increase in this time interval. This situation is natural when the organization is forming key innovative technologies based on core competencies that allow gaining significant competitive advantages. However, it should be noted that in the case of science-intensive industries, competitive advantages are very time-limited, since the technologies used, including innovative ones, have a rapid development by all market players.

The proposed dynamic models show that organizations need to have core competencies to obtain competitive advantage. The acquisition of these competencies and especially their implementation require large financial and time costs. And the time factor plays a decisive role for the knowledge-based organizations competitiveness management.

Let us consider a modification of the proposed economic-mathematical model for the case of delay in time from the competitive advantage influence on the dynamics of competitiveness indicators. To do this, consider formalism based on differential equation with lagging argument.

Differential equations with lagging argument have the following formal form:

$$\frac{dy(t)}{dt} = f(t, y(t), y(t-h)).$$

Such equations simulate a situation when the dynamics of the solution depends not only on the current value of the solution but also on past values (with the lag h).

In the economic and mathematical models in question, we will consider functional differential equations of a more general type:

$$\frac{dy(t)}{dt} = f(t, y(t), y(t-h)) + \int_0^t g(s, y(s))ds.$$

In this equation, the solution already depends not only on the lag, but also on all previous values.

The economic interpretation of these models is that the large science-intensive organizations competitiveness indicators are rather inert, since the competitive advantage that results from the use of the acquired competencies has an indirect effect on competitiveness indicators. There is a certain delay in the chain of "competitiveness of products—the competitiveness of the organization", as improvement of competitiveness of products should be duly reflected in the market, so that would lead to a real competitiveness improvement of the organization. This creates not only time lag processes, but also the processes, where previous values of the indicators of the organization competitiveness are decisive in assessing competitiveness.

On the other hand, different methods of assessing organizations competitiveness can be based on a statistical analysis of their financial and economic activities when evaluating projects and programs implemented. This analysis takes into account the values of competitiveness indicators at previous points in time. It is necessary to use functional differential equations with lagging argument to simulate this situation.

The basic equation with lagging argument describing the dynamics of the competitiveness indicators of the organization, as follows:

$$\frac{dQ(t)}{dt} = A(t)Q(t) + \sum_{k=1}^{K} G_k(t, Q(t), Q(t-h_k)) + \int_0^t g(s, y(s))ds.$$

This model examines the sum of the various lag. The lags themselves, denoted by h_k functions can have a rather complex form. In particular, they can depend on the time or on their eigensolutions. The latter option, the dependence of the lag from the solution, often arises in the tasks of simulating the competitiveness indicators dynamics, since it is the current value of the competitiveness indicators that can determine the time interval at which the value of the competitiveness indicator has effect.

Let us consider a formal definition of such lag:

$$h_k = h_k(t, Q(t)),\ k = 1, 2, \ldots, K.$$

Of course, the lag should have a strictly positive value:

$$h_k(t, Q(t)) > 0,\ k = 1, 2, \ldots, K.$$

These conditions guarantee the mathematical correctness of the problem statement.

In these models should also consider the generalizations associated with the possible risks in the implementation of competitive advantages in managing the competitiveness of organizations.

To do this, use the following equation:

$$\frac{dQ(t)}{dt} = A(t)Q(t) + \sum_{k=1}^{M} B_k(t)G_k(t).$$

Matrix B_k as a realization of random variables Consider a mathematical model when the values of matrix factors deviate from planned values.

Let the planned values of this matrix are as follows:

$$B_k = \begin{pmatrix} b_{11}^k & b_{12}^k & \cdots & b_{1N_k}^k \\ b_{21}^k & b_{22}^k & \cdots & b_{2N_k}^k \\ \cdots & \cdots & \cdots & \cdots \\ b_{11}^k & b_{11}^k & \cdots & b_{NN_k}^k \end{pmatrix}.$$

Then we consider a matrix consisting of the following realizations of random processes:

$$\tilde{B}_k = \begin{pmatrix} \xi_{11} & \xi_{12} & \cdots & \xi_{1N_k} \\ \xi_{21} & \xi_{22} & \cdots & \xi_{2N_k} \\ \cdots & \cdots & \cdots & \cdots \\ \xi_{N1} & \xi_{N2} & \cdots & \xi_{NN_k} \end{pmatrix}.$$

These variables (or realizations of random processes) can have different probability distributions, since they depend on various economic nuances when building the economic-mathematical model.

As an often used probability distribution, we can take lognormal distribution as an example.

This distribution has the following density distribution:

$$f_\xi(x) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-(\ln\ x-\mu)^2/2\sigma^2}.$$

It defines variables that have only positive values.

However, in the economic-mathematical models construction taking into account random factors associated with the use of competitive advantage there may be options when these factors have only a negative impact on competitiveness indicators. There are also situations where the influence of random factors on the competitiveness indicators is positive.

Thus, there was proposed and examined an economic-mathematical model to enable estimating competitiveness of high-tech industry organizations based on competitive advantage that arise on the basis of core competencies. The finite-machine models are proposed that allow modeling the chain of "competence-innovation-competitiveness".

Dynamic models modified taking into account the lagging effect in the system of organization competitiveness management through competencies of the are examined. These modifications are based on difference-differential and functional-differential equations. The examined models with the use of equations with lagging argument allow building accurate models for real situations. Also, questions of accounting for random factors in assessing the organizations competitiveness indicators are considered.

The developed mathematical models for assessing the organizations competitiveness can be applied in the creation of information and analytical systems to support strategic solutions in the field of high-tech organizations competitiveness management.

4.3 Mechanism of Corporation's Competitiveness Management Using the Knowledge Management Model

The competence management system is an integral part of the corporate competitiveness management system and should be formed together with other components. Only data on already formalized knowledge should be input in the generalized competence management process. These are available patents, licenses, technologies and other intellectual property objects owned by the corporation. These competencies already have a generally accepted classification system for scientific fields (a system for classifying patent information). However, this should also include implicit competencies, e.g. non-formalized intellectual property, technological solutions, innovative designs, etc.

The corporation's competencies and innovations management center can act as the executor of such work. The center's staff will administrate information bases, and experts in subject areas will provide the units of the organization with consulting services on information search. In fact, the competence and innovation management center is a professional intermediary between the bearer of knowledge and competencies and the consumer.

A graphical model of knowledge management using the competence and innovation management center is shown in Fig. 4.4.

The overall objective of this system is the formalization and classification of all organization's competencies with the ability to distribute them.

Thus, it becomes obvious that the competencies management of is the basis of sustainable competitive advantage of the corporation. To implement the competence management process, it is necessary to develop an algorithm to identify the organization core competencies through competence and innovation management centers.

The proposed approach considers the competence and innovation management center as a special structural unit of the organization that monitors one or more areas of activity that are prioritized for the corporation and ensure the accumulation of relevant competencies in order to obtain maximum benefit from them. T. Andrusenko, researcher of such structures notes that the idea in itself is not

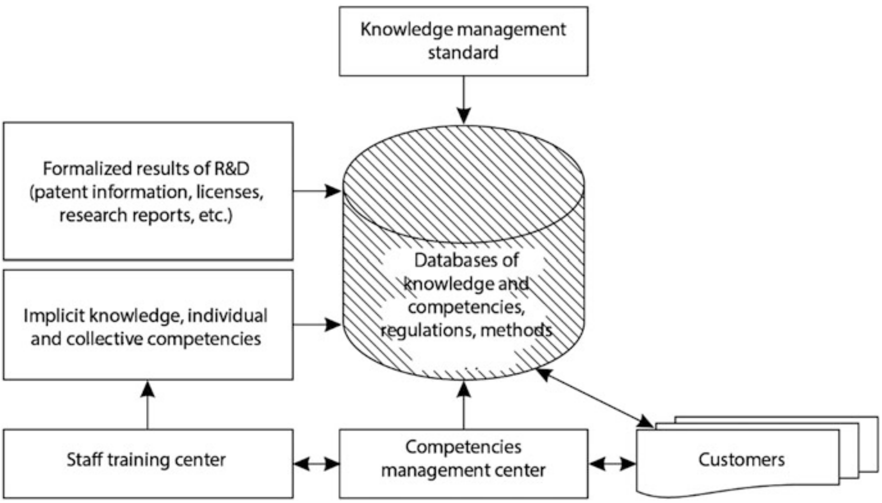

Fig. 4.4 Forming a knowledge management model using the competence and innovation management center. Source: Compiled by the authors

new. The departments of scientific and technical information, the standardization and quality groups, archives, and other divisions in varying degrees are called upon to embody it. However, talking about competence and innovation management centers, it is more about processes, knowledge and experts integration, as well as effective IT communications. The main thing in this case is not information in itself, but the connections of people creating new competencies. The researcher states that in the world practice four types of competence management are most common:

1. *Units for the accumulation of best practices.* Their main task is to collect, formalize and distribute the types of experience which showed the best results. Specialists of such centers define and describe processes, prepare technical and technological recommendations and standards, develop various management programs. T. Andrusenko points to examples when, based on the introduction of best practices, the development time of products was reduced by 30–40 times, and 60–65% of accumulated intellectual resources were reused in new projects;
2. *Units on technological standards development.* In this case, attention is focused on software development and hardware selection, standardization of processes on a single technological platform is carried out, experience in using the chosen platform is being developed (in the absence of technological resources exchange);
3. *Units for distributed services.* These units specialize in optimizing the use of resources by participating teams of a particular project, support knowledge management initiatives (including training in product specificity, technological benchmarking, etc.);
4. *Units of centralized service.* Such units manage the integration of the main processes and data, accompany projects, ensure the data quality and resources development, and develop requirements and standards for technical and information subsystems, facilitating the accumulation and exchange of knowledge.

Each type of competence and innovation management center has its advantages and disadvantages, and there is no optimal model for a particular organization. However, they are able to ensure the elimination of duplication of processes and functions through the reuse of knowledge, optimization of projects implementation and the use of resources, savings on the consulting services, etc.

It is also possible to organize and successfully operate competence and innovation management centers not only within a single company. For example, Finland has the practice of establishing the so-called strategic competencies and innovations management centers supported and funded by the state and the Finnish Funding Agency for Innovation TEKES. Such centers presuppose cooperation of enterprises, scientific organizations and financial institutions in those areas of activity that are of priority for Finland.

Currently competence and innovation management centers are being created in five areas:

1. Energy and ecology;
2. Metal working and mechanical engineering;
3. Forest industry;

4. Industry and services in the field of information technology and telecommunications;
5. Health and well-being.

Participation in the activities of strategic competence and innovation management centers allows to organizations optimizing the research plans, gaining access to new knowledge, increasing innovation pace and efficiency. The terms of R&D are shortened, contacts between enterprises and scientific organizations are strengthened.

Nevertheless, we emphasize once again that a competence and innovation management center can be not only special structural units of the organization or specialized entities that ensure the cooperation of commercial production structures and scientific organizations. Organizations—participants of integrated structures can also be the competence and innovation management centers as the bearers of competencies necessary and sufficient for the formation and development of integrated education.

A meaningful analysis of theoretical developments and accumulated practical experience in the creation and operation of competence and innovation management centers allows us speaking of them as organizations that specialize in the implementation of a specific technological function or on a set of such functions, which makes it possible to talk about subject specialization. The content of the technological functions can be the most diverse, including those related to the sphere of management.

Thus, if we formulate the problem of the knowledge-intensive industries development through the creation and support of the competence and innovation management centers, we should talk about the rational distribution of functions among a multitude of organizations specializing in this or that area and ensuring the sustainable cooperation of these organizations.

However, before proceeding to the formation of relationship principles for high-tech corporations' competence and innovation management centers, it seems appropriate to dwell on the features of the environment in which those centers will be used as a means of the industry competitiveness improvement.

Practical aspects and specifics of functioning of the industry can be described as follows: its constituent organizations are specialized in the subject and detailed types. The difference in subject specialization does not exclude, but often assumes the identical technological specialization. It is much easier to provide technological preparation of production and to organize the release of new products in such conditions; a new project is quite efficient in economic terms.

Production at most enterprises in the industry is of a combined type. The vertical form of combination prevails, which provides considerable freedom for enterprises and organizations of the industry in the formation of both strategic and operational management decisions.

In addition to technological, organizational and economic factors, also factors related to property relations have a certain influence on the functioning of the industry. It is obvious that to date, property relations have very little influence on the industrial policy of the sector and the measures to ensure its economic efficiency. Mechanisms that ensure the formation and implementation of such solutions have not been created to date. Above all, this refers to the regulation of internal competition in the industry. The regulation of the processes of aligning the interests and finding compromises for individual elements of science-intensive branch, primarily at the level of strategic management, seems to be a quite efficient tool for drawing the industry out of the current difficult situation.

High-tech instrumentation is unstable today. The transition process in a system, especially in case of a large number of operators with the authority to change the operation regulations, leads to the fact that the objective economic and organizational patterns are distorted; their identification becomes more difficult, the indicators become more volatile. This, in turn, causes narrowing of the planning horizon. The share of strategic decisions is decreasing, and they become less significant from the point of view of decision makers. The operational decisions prevail, as already noted. It is difficult to organize an effective interaction between business entities in this situation.

Concerning the theoretical developments on this topic, it is possible to state a few considerations. The branch in the modern sense is a cluster functioning as a dynamic system of strategic alliances.

The main tasks of the competence and innovation management centers are accumulating, storing and providing transfer of knowledge. As a result, the enterprises of the cluster should improve the efficiency of their activities through the information exchange development. The traditional efficiency indicator of economic entities is the gross product and its dynamics. The gross industrial product is a quite suitable indicator in the initial stages of analysis, especially if analysts have representative statistics of its dynamics. But when solving the problems of ensuring the efficiency and competitiveness of the industry, it is hardly advisable to restrict only to the gross values of the aggregate industry product. Of special interest in this case is the structure of the gross product, its compliance with the strategic and long-term objectives of the industry, as well as the effect of the coordinated operation of enterprises. In modern terms, this can be defined as a synergistic effect.

In a number of works attempts have been made to formulate requirements for a methodological basis for evaluating the synergistic effect. In particular, the emergence in the coordinated work process of cluster structures of the so-called network effect that determines the quality assessment of managing the industry as a whole is indicated.

As is known, the strategy determines the composition of the planned work. The work, in turn, depends on the characteristics of the products. Таким образом, специфика продукции может быть той базой, которая предопределит рациональное распределение функций внутри кластера. Rational distribution of functions between the entities of the industry proves to be an important means of regulating such opposing relations as cooperation and competition.

The strategic management function implementation needs a long-term industry development program. It is easy to see the contradiction in this statement, which is that the cluster by definition is a self-regulating system. At first glance, this precludes making any directive decisions in relation to the components of the cluster. However, although this contradiction is consistent with the existing notions about what a cluster is and how it should function, it does not fully correspond to the realities of the organizational and economic systems to which the industry belongs.

Organizations, which are components of the industry, including those recognized as competencies and innovations management centers, are subjects of economic activity with well-defined goals. Combining these organizations in the cluster through economic or administrative measures does not deprive them of the system's active elements functions. It is possible to form a cluster and ensure its sustainable functioning, only by retaining for the organizations sufficient opportunities to set goals and the resources to achieve them. Finding a compromise is necessary, although the strategic industry development program presented in some form of Pareto set also may occur to be such a compromise. Another thing is that the industry does not exist by itself, but is created and maintained in the interests of some super system. That is, in the process of forming a development strategy we should take into account first of all the interests of a party, which perhaps is not formally represented in the cluster. Such representation should be provided. This is the reason for the necessity of one of the basic principles of successful functioning of the industry based on specialized organizations—centers of responsibility for solving certain industry-wide tasks. Such a center is the competence and innovation management center, consolidating the industry's achievements for the purpose of their joint use by all cluster structures.

Establishment of the competencies and innovations management center will ensure the functioning consistency of the industry and its key components. In addition, strategic development programs which, above all, should be sustainable in the long run, do not meet this requirement; the factors that determine the variability of these programs are obviously irrational; there is no mechanism ensuring the co-ordination of operators in the long term.

Identification of competencies and their level assessment If knowledge creation is a function of relevant R&D units, and its use is mainly related to production, then the remaining three processes can be successfully centralized in the framework of establishing competence and innovation management centers. Competencies formalization can be implemented in several consecutive stages.

The first stage. Assessing consumer properties of products and services. This helps to identify the competitiveness of specific products. Next comes the identification of product competencies.

The second stage. To identify the full range of competencies (incl. corporate ones) and pre-allocate key positions, expert assessment can be used: questionnaires, round tables, etc. A list of all identified competencies related to certain business processes will be created here.

The third stage. The business processes, which were selected as the most important in the first two steps, are formalized in the IDEF business process standard and are quantified with the reference samples using the OPM3 standard. Thus, superiority will be objectively confirmed or rejected.

This sequence is represented graphically in Fig. 4.5. The second universal mechanism for knowledge competencies management is the comparison of existing business processes "as is" with the best practices.

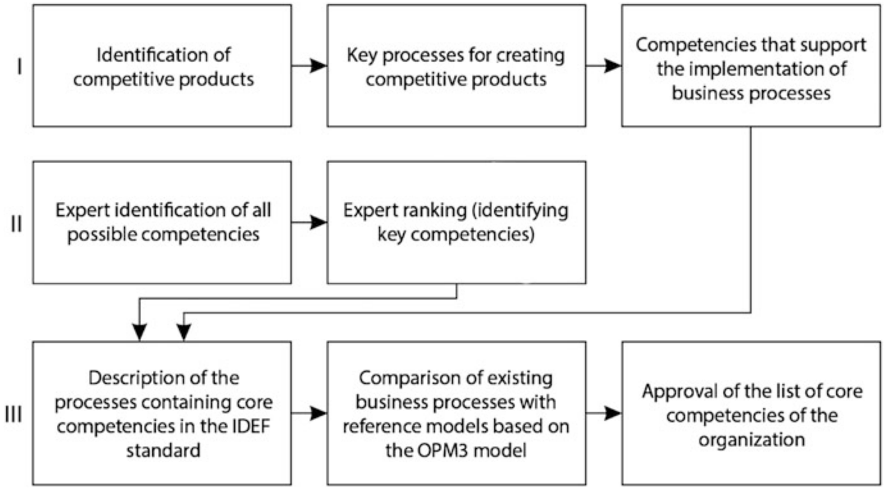

Fig. 4.5 Scheme of identifying core competencies. Source: Compiled by the authors

Next, consider the ORM3 standard, one of the most well-known models of the company's maturity assessment. The main goal of ORM3 standard implementing is to support the purposeful development of the organization's ability to implement the strategy through the successful projects implementation based on continuous self-esteem in comparison to world leaders.

Technique for identifying organizational and managerial competencies The objectives of the standard implementation are: improving understanding of the links between the organizational strategy implementation and the business processes management through the related competencies management; identifying the processes necessary to implement strategies through business process management; identifying the abilities an organization must have to reliably turn a strategy into projects and the results of their successful implementation; identifying the interdependencies between the required abilities; identifying ways to improve the organizational projects management maturity using the standard; providing the practical guidance for the application of the standard in organizations.

The reasons for choosing the standard ORM3: conformity to the current strategic development objectives of many high-tech industries; relative ease of implementation and visibility of comparative procedures; prevalence in large companies-leaders in the world market; ready descriptions of the best business practices.

Using this technique is an important element of the enterprise performance monitoring system. It positively characterizes not only the knowledge management, but also the overall innovative potential.

At the same time, it should be noted that the organization's competencies can not be limited to project management. There are marketing, logistics, infrastructure, financial and other competencies that are of a general nature. There are special standard models for them. For example, SCOR-models are widely spread in logistical processes. They in their essence are the best practices, i.e. they repeat the idea of the OPM3 standard, models of organizational maturity, etc.

The main problem of introducing comparative approaches to competencies analysis in a high-tech corporation is the absence of a formal “as is” description of business processes.

The OPM3 reference business processes bases are paid, they are focused on the American and European common practices. They operate with the organization's standard competencies which are already in the open access, they are not unique. However, to evaluate the object's uniqueness it is necessary to compare it to its closest analogues; the leader should be the best of all available alternatives; and the OPM3 standard can be used for such comparison. Strictly speaking, the absence of analogues in the world does not always indicate the exclusivity of the object. The lack of alternatives often means a dead-end path of development.

The most radical approach here is to create own base of the best business models, which will encompass the experience of all national high-tech corporations. This will be a long process, which should begin at the corporate level with a description of the situation “as is” in one of the pre-agreed standards (this can be IDEF5 or Axapta). Only after that, it is possible to proceed to the consolidation of data on all high-tech enterprises. This database would be useful not only to state-owned companies, but also private entities, as they would also enter the system of experience exchange; it will be easier for subcontractors to understand the customer; government entities will be able to quickly obtain data on the real laboriousness of a process. The creation of such a database of best practices can be entrusted to the competencies and innovation management center.

Chapter 5
The Conceptual Model of Corporate Network of the Competencies and Innovation Management Centers

5.1 The Concept of Formation of Corporate Network of Competencies and Innovation Management Centers

The formation of an organizational concept for the knowledge-based industry management based on the competencies and innovation management centers supposes, first of all, the opportunity to analyze the variety of such concepts and to make optimal just-in-time decisions.

Thus, it can be argued that the strategic management or the conceptual model of the industry as a system in which the core functions are implemented by the competencies and innovation management centers should be the information base for the strategic decisions making. At the same time, considering the requirements to the problems of forming a strategy and the very sense of this term, such a base should contain certain rules for drawing conclusions and making decisions. That is, it is not about information itself, even structured in accordance with the specifics of the subject domain being researched, but exactly about knowledge.

At present, there are numerous examples of successful solution of the problem of the formation and application of this kind of conceptual models focused on making strategic decisions in conditions of both structural and parametric uncertainty. First of all, such techniques as the Eisenhower matrix, the SWOT analysis, the matrix of the Boston Consulting Group (BCG), the Whitmore model should be mentioned. The format of the models named above corresponds to the specifics of the problem under study, but the possibilities of these models are limited. Many details of forming a system of competencies and innovation management centers, important from the point of view of methods and means can not be taken into account in these models.

The ADL/LC model best fits to the issues studied. This model was developed as a means of strategic analysis and planning for multidisciplinary organizations.

The very ADL model is formed on the assumption that the organization in its development goes through four stages of the life cycle and at each of these stages it is

A. Chursin, A. Tyulin, *Competence Management and Competitive Product Development*, https://doi.org/10.1007/978-3-319-75085-9_5

able to occupy one of the five competitive positions in the market. The model is a matrix of 20 elements, corresponding to different combinations of stages of the life cycle and competitive positions.

The ADL technique is used in the strategic decision-making process in a certain sequence. First of all, the position of the organization in the matrix is identified. At the second stage, in accordance with the found position, a certain strategic decision is selected from among the sample ones. Such a solution is formulated in a fairly general form and requires further refining and concretization. The ADL concept includes a sufficiently large number of refined strategies. The choice of such refined strategies suggests the consideration of not only qualitative indicators, but also quantitative ones, in particular, the return on net assets.

The ADL model assumes certain conditions, the observance of which contributes to the successful practical application of this technique. First of all, it is considered that the organization's lines of business must be at different stages of the life cycle. Further, the total cash flow from all business lines is assumed to be non-negative, which makes the organization's prospects more favorable. In addition, the weighted average return on net assets is recognized as consistent with management's notions of efficient operation. And, finally, the ADL model is recommended for practical application on the assumption that the number of business lines of the organization is quite large.

The interesting thing is that the ADL model uses a special indicator of internal redistribution, which is calculated as the proportion of the organization's funds that are reinvested in a certain lines of business. This indicator reflects the ratio of the change in the value of assets to the change in the value of operative stock in percentage terms, where the change in the value of assets is the difference in the value of assets (less depreciation) in the current and previous years, and the value of operative stock is defined as the amount of profit less taxes plus depreciation.

It is believed that usually an analysis of organizations belonging to different industries, taking into account the specifics of the life cycle stages can be reduced to fairly routine procedures. However, when it comes to high-tech industries, the methodology can lead to unreliable results and poor-quality solutions, since it is in high-tech industries that the life cycle can be short enough.

In addition to the instability of the methodology in relation to the life cycle, ADL procedures can be critical in terms of the competitive position, which in different industries can manifest itself in different ways. ADL's methodology assumes that competition at the nascent stage is always fragmentary, and the concentration is formed at the stage of maturity.

The ADL model illustrates the basic approach to the formation of a conceptual model as a tool for developing a strategy. The main idea of the methodology, ensuring its correctness, visibility and practical efficiency, is to identify the basic qualitative indicators, which help to eliminate structural uncertainty when developing solutions. Of course, such indicators are used in the BCG model, and in other similar mentioned above models of strategic decision making, but the approach of ADL analysts is most thoroughly worked out and justified. Another thing is that, in an effort to complete the method by obtaining unambiguous quantitative results, its authors seem to have resorted to rather strong assumptions that can hardly be used without adjustment in the practice of management. It is possible that this is due to the fact that the objects of analysis of this study and objects analyzed by ADL authors are quite different. The organization, even a multidisciplinary one, cannot serve as a direct analogue of the industry intended for the production of complexes in the terminology of the Unified Design Documentation System standards. An adjustment is required, and seems to be significant.

Thus, to improve the efficiency of the competence and innovation management centers, it seems appropriate to divide their results by the specific activities into internal and external.

The work on establishing an internal for the competencies and innovations management center is supposedly of a project-systematic nature: it would be of project nature at the first stage, and systematic and at the second stage, after the launch of the prototype center (development and consolidation of the center by its management). At the first, project stage, the project manager, acting on the basis of the project charter and the concept of the center, should act as the head of the center. At the second stage, a managerial role can be transferred to the second-level or third-level officer acting on the basis of the job description.

The internal competencies and innovation management center should be the core of practical work on automation of the company's production processes: it implements relevant projects, non-core work may be referred under subcontract. The results of the activities should be divided into two parts: internal and external.

The results of the project activity in the interests of clients are external one, the internal results are the intellectual assets (the competence itself, various documentation, business process models, applied and utility software, approved solutions, etc.) reusable as part of external results.

From the point of view of the output, the center may seem identical to the external integrator company. But the integrator company's interest is to increase the number of customers, including various industries, while the internal competencies and innovation management center has a fixed number of customers and their production processes are predefined. This symbiotic relationship with the client requires a much higher quality of the services provided.

In the internal competencies and innovation management center there should be established a system of training and reproduction of personnel who are well versed in the problems of clients. For example, a mentoring school can be established where specialists with experience of working in the client's production will be recruited as mentors (key personnel), and the graduates of profession-oriented universities be recruited as young specialists.

Quality controllers should be involved as much as possible in the processes of the center; they should also carry out expertise of project and other output documents.

As an example of the results of external activities of the competencies and innovation management center, the competencies and technologies may be transferred from the automotive industry to aviation, as shown in Fig. 5.1.

As already mentioned, the main means of forming a strategy model for a high-tech industry based on competencies and innovation management centers should be

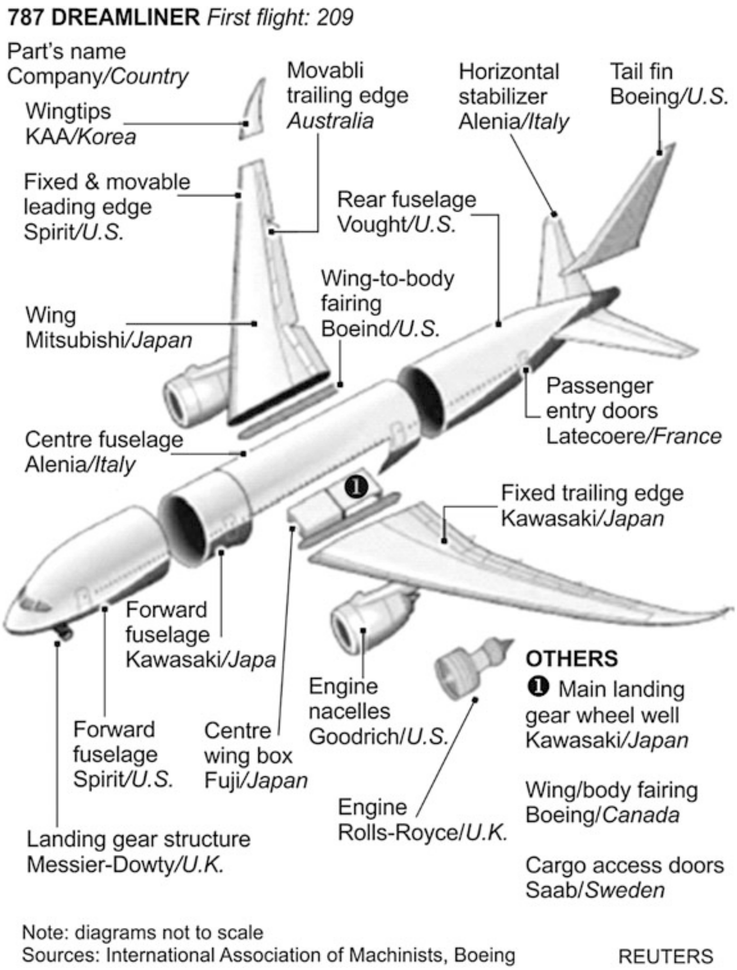

Fig. 5.1 Transfer of competencies and technology from the automotive industry to aviation

the expert procedures: the experts are presented with as full, clear and reliable up-to-date information as possible. The starting point for the model formation should be to identify the most significant factors that determine the strategy being developed. These factors are indicators that can be interpreted as axes of coordinates in the attribute space. Combining such indicators can create the industrial classifier of strategic management, similar to the classifier shown in Fig. 5.2.

This figure presents a systematized description of the generalized problem of organization management that forms a three-dimensional attribute space with the axes "planning horizon—management functions—infrastructure". The potential variety of such classifiers is very high; this can be considered an indirect proof of the efficiency of such an approach to the conceptual model development.

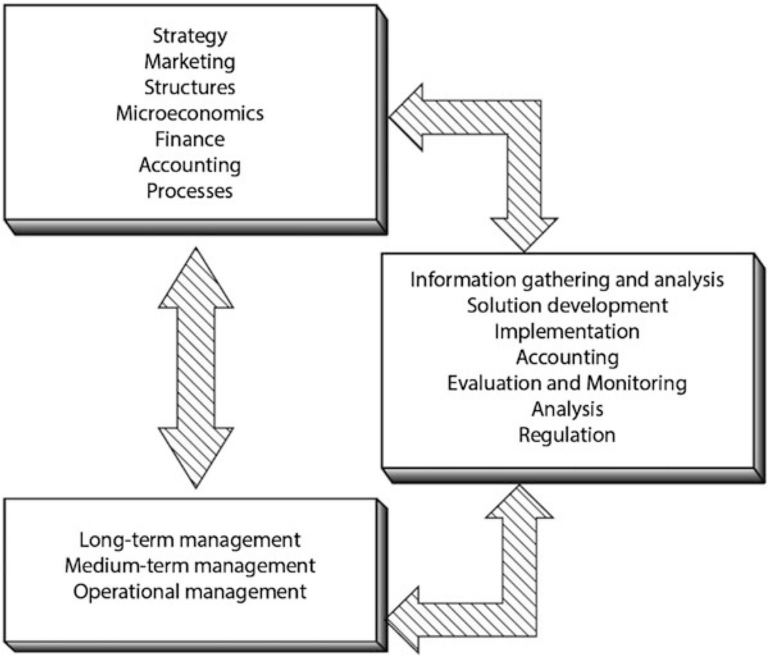

Fig. 5.2 Three-dimensional classification of management

The adaptation of the generalized management classifier in Fig. 5.2 to the goals and objectives of the monograph requires, first of all, clarification of the substantive categories. Obviously, one of these categories should be the nomenclature of strategies. The functional strategies include competition strategy, research and development strategy, production operations and production development strategy, marketing and sales strategy, personnel management strategy, financial strategy.

As an example of the applicability of the proposed approach to knowledge-based industries, it is proposed that it be tested in the instrumentation industry. So, to clarify the meaning of the "type of strategy" category, a group qualitative expert evaluation in the form of a focus group was conducted. Eight specialists working in the aircraft instrument industry, as well as economists specializing in strategic management took part in the expert evaluation. Under scenario among other questions experts were asked about the types of strategic tasks that require coordination in the decision process, as well as on possible subjects of such coordination. Experts were informed that the purpose of the examination should be to determine the nomenclature of the competencies and innovation management centers for the period until 2020.

Based on the results of the discussion in the process of the examination and the subsequent analysis of the discussion, a conclusion was drawn that among the possible strategic tasks, in addition to those initially presented to experts, it is necessary to add the strategy for service capabilities of the industry developing, and, in addition, such an important set of tasks, related to the quality management of all units in the aircraft instrument cluster, including certification of products.

Another category that characterizes the peculiarity of the industry and a is very important aspect of its functioning is the specificity of the products.

Currently, the aircraft instrument cluster production that can be divided into the following groups:

– Avionics (on-board radio electronic equipment);
– Electronic warfare and electronic intelligence;
– Systems and means of state recognition
– Measuring apparatus;
– Connectors and cables.

According to the degree of complexity and level of integration of products it can be divided into:

– Parts;
– Units;
– Complexes;
– Sets.

This information is objective and can be included in the conceptual model without clarification and adjustment by experts. Thus, the second coordinate axis or the category characterizing the industry is the indicator of products complexity.

The avionics group includes such complex products as navigational complexes, systems and complexes of indication and observation of various degrees of integration. Products related to electronic intelligence and electronic warfare, from the point of view of complexity also belong to the complexes, and these complexes differ in their performance, since they are intended for use under different conditions. The same can be said about systems and means of state recognition.

The product range of the aircraft instrument industry also includes products of a lower degree of integration. Such products include devices for measuring various physical quantities and generating signals, as well as connectors and cables. These products in most can be attributed to a group of components or assembly units. There is no need for a broad cooperation to produce them. The same can be said about a group of products not related to aircraft instrumentation, such as medical equipment, equipment for fuel and energy complex, housing and communal services. Parts and sets are products of a low degree of integration, components are of medium degree of integration, and systems and complexes are of high degree. This should be taken as the range of values of the indicator.

The generating set of potential competencies and innovation management centers can be limited to this two-dimensional space. In this case, a faceted classification scheme is formed. It has two-parameter formula; one parameter can take eight values, and the second one can take either three or five values in accordance with the division of the industry's production into product groups. The advantages of such representation are clarity, compactness, and the open nature of the generating sets.

However, the results of an expert survey based on such information may not be enough for creating competencies and innovation management centers. By analogy with the conceptual model of ADL, it is necessary to provide model solutions in the model that determine the functions of such centers. If such information is not provided in the model, the model will not provide the conditions for making adequate, correct and effective management decisions. The arbitrariness of the manager and the excesses of the performers can be extremely important. It is these typical strategic-level solutions that should be the prerogative of the competencies and innovation management centers. To ensure that the standard solutions do not contradict the goals and objectives set for the industry, a third category is needed; its meaning is determined by the infrastructure integration criteria considered at the previous stage.

The values of the third indicator may include such integration activities as:

- Workflow regulations;
- Regulations for the training and certification of personnel of all categories;
- Regulations for the formation of strategic plans and the coordination of operational plans;
- Regulations for material and financial resources allocation;
- Information technology used.

Thus, the basic elements of the concept of networking of the competencies and innovation management centres form the model presented in Fig. 5.3.

These elements are combined into three groups:

- Functional strategies;
- Production integration levels;

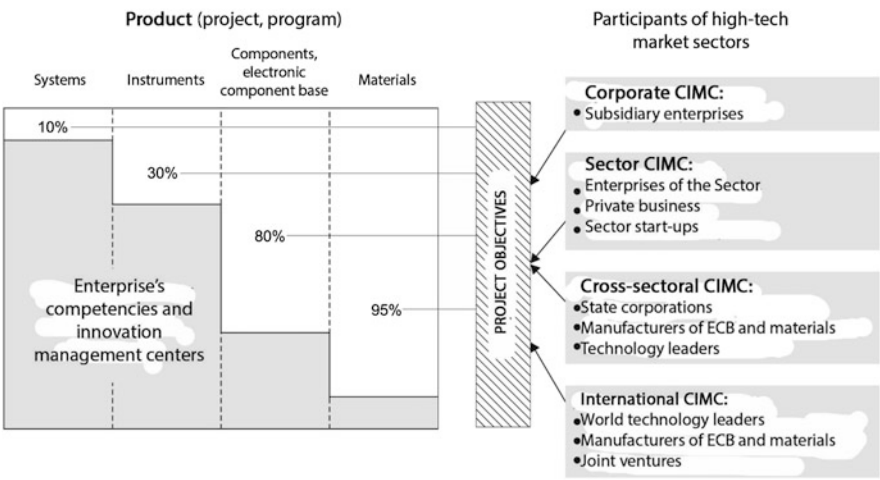

Fig. 5.3 General view of the conceptual model for establishing industry network of competencies and innovation management centers

– Organizational measures of an integrative nature.

Various options for combining the elements of these groups allow forming the industry network of competencies and innovation management centers, depending on external and intraindustry factors, as well as management preferences and values.

5.2 Approaches to Managing the Development and Operation of the Corporate Network of Competencies and Innovation Management Centers

Formation of the theoretical basis for building an industry network of competencies and innovation management centers, as well as the best possible consideration of individual management preferences does not exhaust the problem of improving the industry efficiency. A system of recommendations on the practical implementation of the major theoretical provisions and mechanisms of the industry functioning and management is needed.

The peculiarity of the problem is that strict formal models and algorithms for the preparation and making such strategic decisions are of low efficiency in conditions of high uncertainty, and the quality of those decisions is poor. The most common methods to provide in practice the formation of a strategy for the complex objects management development are informal, intuitive methods, the inclusion of which in management tools is largely due to the traditions and common sense of decision-makers, as well as analogies born in the decision-developing process. It is rather difficult to object to such a state of affairs, but the weak point of following traditions is that traditional norms are optional for use, and even a detailed conceptual model does not guarantee their use in a process. In addition, intuitive methods of making managerial decisions do not involve a detailed elaboration.

Before formulating the basic provisions, it should be borne in mind that the practice of solving the problem of high-tech industry activities efficiency improvement, like many other similar problems, is not a linear process, but a cyclical one where each iteration is a refinement and extension of the earlier obtained results. Obviously, such a cycle is mainly due to the high level of uncertainty and the lack of resources, especially the temporary ones, which are necessary to drastically reduce this uncertainty within the one-time decision-preparation process. One can draw an analogy of practical approaches to the problem being solved to the well-known Juran's spiral of progress in quality, when the stereotyped actions that are part of the management cycle are repeated many times with the use of additional information and provide the solution of tasks of quality management in the changed circumstances. Of course, the Juran spiral's components and the iterations of industry progress on the basis of competence and innovation management centers, have different content. A priori, it can be argued that it is appropriate and correct to implement the improvement of the competencies and innovation management centers network within the sequence of the stages "preliminary industry survey—

development of recommendations for improving centers network—implementation of recommendations—monitoring".

Another feature of the problem is the apparent lack of clearly defined initial and end moments of solving process. Uncertainty does not allow fixing these moments and related goals, the range of the indicators under control and their control values. These tasks actually represent individual control functions. These include the problem of improving the industrial structure.

The way out of this situation, empirically found in the process of solving similar problems, prescribes planning the activities to improve the industry structure by queues within the framework of individual management cycles. It should be noted that, in practice the principle of priority of solving such constantly urgent tasks is often violated, and attempts are made to eliminate all identified shortcomings in one management cycle; this leads to waste of resources and can disrupt the functioning of the object under control to a large extent.

These features of the problem lead to the conclusion that the project approach should be the basis for the practical implementation of methods for improving the industry network of competencies and innovation management centers. Obviously, the provisions of the project approach can be useful in solving specific tasks of industry management.

Structural uncertainty, largely dependent on the managerial preferences, can not be completely eliminated, even if there is a high-quality conceptual model. So the process of building an efficient competencies and innovation management centers network can be implemented mainly as a sequence of qualitative examinations, including interviews and focus groups.

If to sum up practical experience of implementation of certain theoretical provisions in the field of complex objects management, the algorithm for managing the development and functioning of corporate network of the competencies and innovation management centers can be represented in the form shown in Fig. 5.4. The individual components of this algorithm require explanations. Before conducting a pre-project survey, it is necessary to formulate a program for such a survey. This program should take into account a fairly large number of interrelated factors, the links between many of which can not be formally defined and quantified.

The set of data required for the control object current state analysis should advisably include:

- Information on the structure of the branch business and business logic, including the nomenclature of the organizational units forming the industry, and the relationships between them, conditioned by the property relations;
- Data describing the general state of the industry, including information on the financial, personnel, scientific, technical and other resources;
- Analysis of product lines of the industry, forecast of the main trends in avionics market, as well as analysis of the possibilities of standardization and unification of the industry's products;
- Data on the enterprises' products position in the market, including information on competitors, partners and the dynamics of intra-industry cooperation;

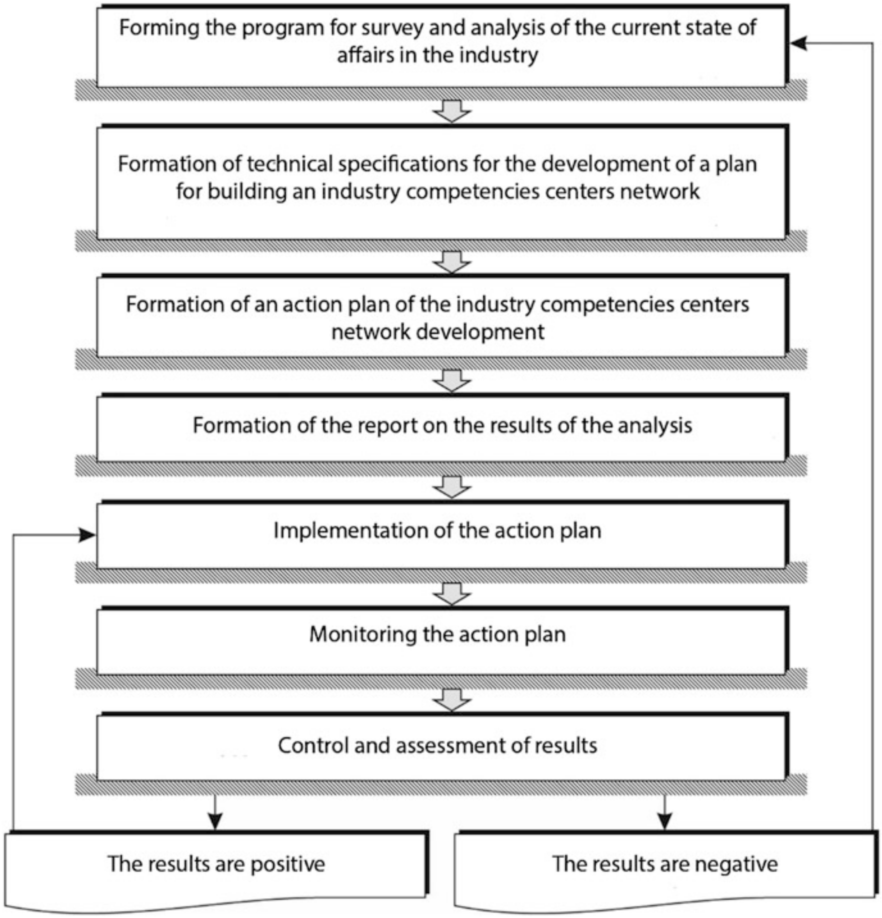

Fig. 5.4 Block diagram of the algorithm for managing the development and operation of the corporate network of competencies and innovation management centers

– Initial data on the engineering and technical state of the enterprise;
– Information on the design methods and tools used, pre-production engineering, logistical support, operations management, information technology.

In addition to the aforementioned areas of the aircraft instrument industry pre-project analysis, the analysis program should include data on the risks associated with the core business and possible alternatives to the portfolio of business lines included in the paradigm of preparing and making managerial decisions. Given the specifics of the problem being solved, special attention should be paid to the interaction of organizational units, and the processes implemented in the industry.

The data groups listed above are mainly qualitative data. This seems natural. However, in order to exclude to some extent the subjectivity, which is due precisely to the qualitative nature of the data, quantitative indicators should also be included in the survey program, as they may reflect the features of the industry more fully and can serve as objective benchmarks. Such quantitative data, which can be considered the most informative, should include:

- The share of innovative products in the industry revenue;
- The average number of employees in the industry;
- Output per employee of the industry;
- The average wage in the industry;
- Net profit margin;
- Market capitalization;
- Return on assets;
- Share of completed state defense orders;
- The growth rate of revenues from the sale of military and civilian products in fixed prices in supplies to both the domestic and foreign markets;
- The share of complex products (complexes) in revenue.

As an explanation, it should be noted that products with a significant portion of the value added can be considered innovative. In practice, it is hardly possible to establish the value of the share of value added for a certain type of product. In this respect, the concept of innovative products may have various interpretations, and the meaning of the first of these indicators can be defined as the industry consensus.

In addition, the program of the pre-project survey of the industry should provide for the collection of information and analysis of business processes implemented at the industry level. In the process of preparing the methodological support for the development and operation of the competencies and innovation management centers corporate network in the aircraft instrument industry, it was concluded that a special section devoted to these issues should be included in the program. Practice shows that the tradition of analyzing business processes using the IDEF modeling tool is justified when moving from the organization level to the level of more complex objects, in this case it is the industry level.

At the same time, the obvious complexity of modeling and analysis of business processes at the industry level requires special attention to the selection of simulated functions. As is known, not all the standards of the IDEF family currently have practical value. The IDEF2 standard has dropped out of the practice as it was considered irrelevant. It makes intuitive sense that information on the industry functioning dynamics presented in some form, first of all, the information on the possibility of temporal coordination of partners' actions within cooperation is quite significant for the decision-maker. However, the activities synchronization of organizational units specializing in the performance of individual functions and work within the production process has a fairly extensive history, and dispatch tasks are usually solved using simple algorithms for operations management. At the same time, these algorithms turn out to be ineffective when going beyond the boundaries of an individual enterprise and, especially, with regard to the problem of creating new products, when almost no base of labor and material standards.

Other IDEF standards should be taken into account when forming a pre-project survey program for the industry. This applies primarily to the IDEF0 and IDEF3 standards. "As-is" models should be included in the report on the survey. Looking ahead, it should be noted that the results of the pre-project analysis in terms of the business processes being implemented turned out to be quite informative and of interest from the point of view of developing and implementing organizational innovations when the analyzed object is operating in a stationary mode. Otherwise, it is difficult to identify stable organizational invariants, and the risks associated with supporting such invariants are assessed as unacceptable.

In addition to data related directly to the surveyed organization, the pre-project survey report should contain the results of external environment analysis, both current and forecast. As a rule, the current data on the markets and competitors behavior are presented as well-defined information in tabular form. The forecast can be presented in various forms and result from the application of a wide variety of methods. Most of these methods are highly formalized and require large amounts of initial information, which makes it difficult to use them in practice and to ensure an acceptable quality and reliability of the forecast. In the course of the pre-project analysis of the aircraft instrument industry, it was established that a forecast of a satisfactory quality can be generated in four variants:

– Protectionist optimistic;
– Competitive optimistic;
– Protectionist pessimistic;
– Competitive pessimistic.

These variants were set up by combinations of two main factors of the external environment: the growth in demand for the industry's products and the support from state institutions, mainly it is the state defense order.

As the experience of the industry survey shows, these four variants of the forecast should basically be qualitative in nature of the forecast information, and only in some cases the prognosists can resort to quantitative estimates to illustrate possible industry development options and provide initial information to analysts who use the well-known fix-and-gap analysis. The protectionist worst-case (pessimistic) scenario was defined as the baseline scenario for the industry development, and analysis shows that the industry will be able to ensure sustainable development indicators even under this scenario, since state support is crucial for innovative lines.

The forecast based on the pre-project analysis of the industry is a number of grouped sets of statements on either strengthening or weakening of a factor.

An additional complication of pre-project analysis and the subsequent formation of the report is that such activities are quite laborious and expensive. They involve the diversion of significant resources from the main activity. Therefore, we can assume that the analysis of the industry in solving the problem of the competencies and innovation management centers development will be carried out within the framework of a more general analysis. Complicating the survey objectives in this case will require the corresponding complication of the analytical tools. As a consequence, with the preservation of the general algorithm for preparing and making managerial strategic decisions, the models used can turn out to be more complicated due to the complication of the management paradigm and the concepts that underlie the decisions made.

The formulation of technical specifications for the development of the competencies and innovation management centers network is a technical task that depends on the specific situation in which the activities plan is developed. The work schedule and planned costs of resources are determined by management. The existing recommendations on the development of such a document summarize the extensive experience to date and are quite obvious. This task is of no theoretical interest.

The algorithm for activities to build the competencies and innovation management centers system, as well as the general algorithm for solving the problem under study is an iterative procedure. The model used in the algorithm is designed to allocate the organizational units of the industry on a competencies set, the preliminary list of which is determined by the results of the pre-project analysis.

Obviously, at the heart of this allocation lies a certain proximity measure "competence—enterprise/organization", determined by the organizational and technical potential of organizational units. It is no less obvious, however, that an objective quantitative evaluation of such proximity is very difficult and, when using any valuation technique, will be rather conditional. Thus, it is expedient to implement the comparison of competencies and organizational units through expert procedures. This subject is quite elaborated, the results on the analysis of the expert methods and the reliability of the quantitative estimates they provide are known. Obviously, the choice of a certain expert evaluation method for selecting the competencies and innovation management centers from among the existing organizational units and to provide these centers with the appropriate authority and responsibility is the prerogative of industry management.

As noted earlier, the meaning of the "competence" category is very diverse and ambiguous. In particular, in terms of creating complex products, it can be difficult, if not impossible, to concentrate necessary competences in one center. In the case when the structure of competencies turns out to be complex, combining separate components of various competencies, the process of allocating competencies and innovation management centers may prove more complicated.

Figure 5.5 presents a more detailed diagram of the algorithm for building a competencies and innovation management centers network. This variant describes the process of forming the matrix of organizational correspondences and is useful when the competences have a complex structure from the point of view of management and it is expedient to implement them on the basis of several interrelated organizational units.

In order to improve the efficiency of the competencies and innovation management centers, it is necessary to systematically assess the organizations competencies in terms of compliance of their level with the world level of science and technology. This process can be performed according to the algorithm given below:

(a) General provisions:

1. The algorithm is intended for assessing the compliance of the organization's production competence to the world level;

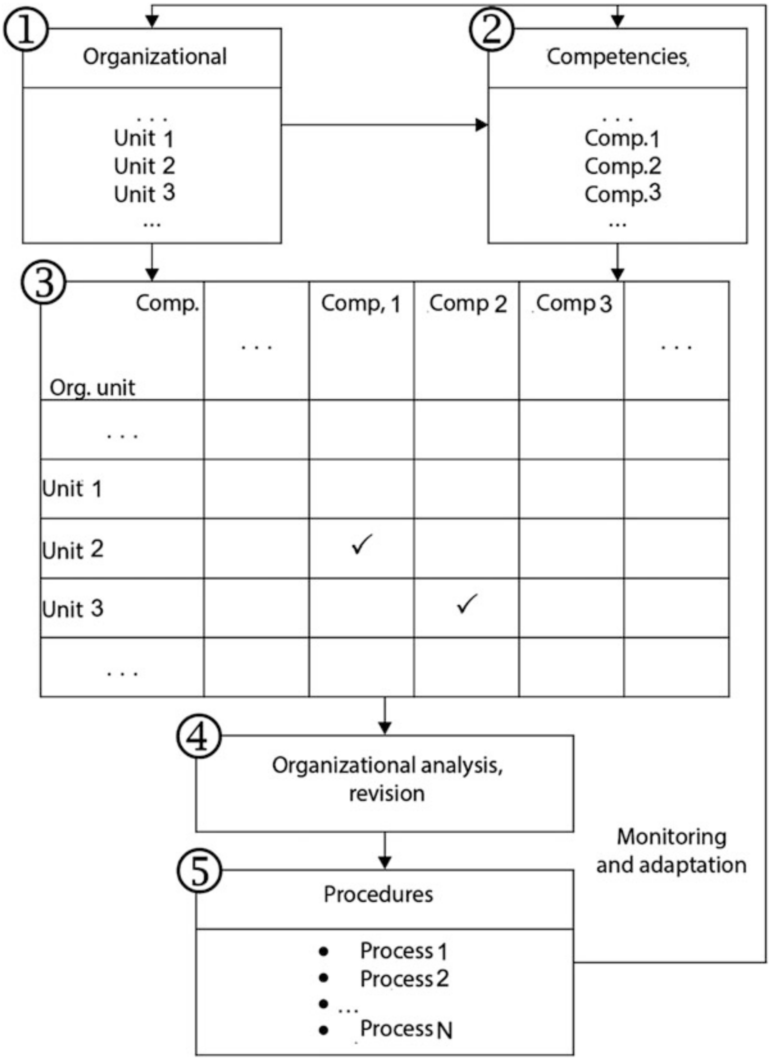

Fig. 5.5 Block diagram of the algorithm for forming a system of competencies and innovation management centers based on organizational units of the industry

2. For the purposes of the algorithm, production competence is understood as technology that is a set of methods for manufacturing products (goods and services), technical means for implementing these methods, and the resources used (hereinafter referred to as the Competence);
3. For the purposes of this Methodology, the world level of quality and/or integral quality of competence or its components is understood as a quantitative characteristic, which allows determining the achieved value as the best

in the world for similar technologies in terms of functional purpose in the evaluation period;

(b) Assessment of compliance of the Competence to the world level:

1. The diagram of assessing the compliance of the competence to the world level is shown in Fig. 5.6;
2. The assessment is carried out in four main stages:

Stage 1. Determination of the requirements for assessing the compliance of competence to the world level, including:

– Verification of the application (information card) containing detailed information on the competence being analyzed for the completeness and reliability of the information contained therein;
– Issue of a conclusion of non-compliance of the application (information card) to the requirements of the instruction for filling it in case such a non-compliance takes place.

Stage 2. Filling in tables of key properties of products (goods and services) produced on the competence basis, and their weights, including:

– Preparation of requirements for sources and methods for obtaining information on the properties of products (goods and services) produced with the use of the competence being evaluated and its analogs from available sources;
– Search for and obtaining information on the properties of products (goods and services) produced with the use of the competence being evaluated and its analogs from available sources;
– Entering the collected information into the tables of key properties and their weights.

Stage 3. Filling in tables of properties values and determining the best and worst threshold quantities of the indicators characterizing compliance of the competence to the world level, including:

– Preparation of requirements for sources and methods for obtaining information on the values of properties of the competence and/or the products (goods and services) produced with the use of the competence being evaluated and its analogs;
– Search for similar technologies and/or products (goods and services) produced with the help of similar technologies;
– Search for and obtaining information the values of the properties of products (goods and services) produced with the help of similar technologies;
– Entering information on the values of the properties of the evaluated technology and/or products (goods and services) produced using this technology and its analogues;
– Calculation of threshold quantities and choosing the best values of indicators characterizing the compliance of competence to the world level, using the

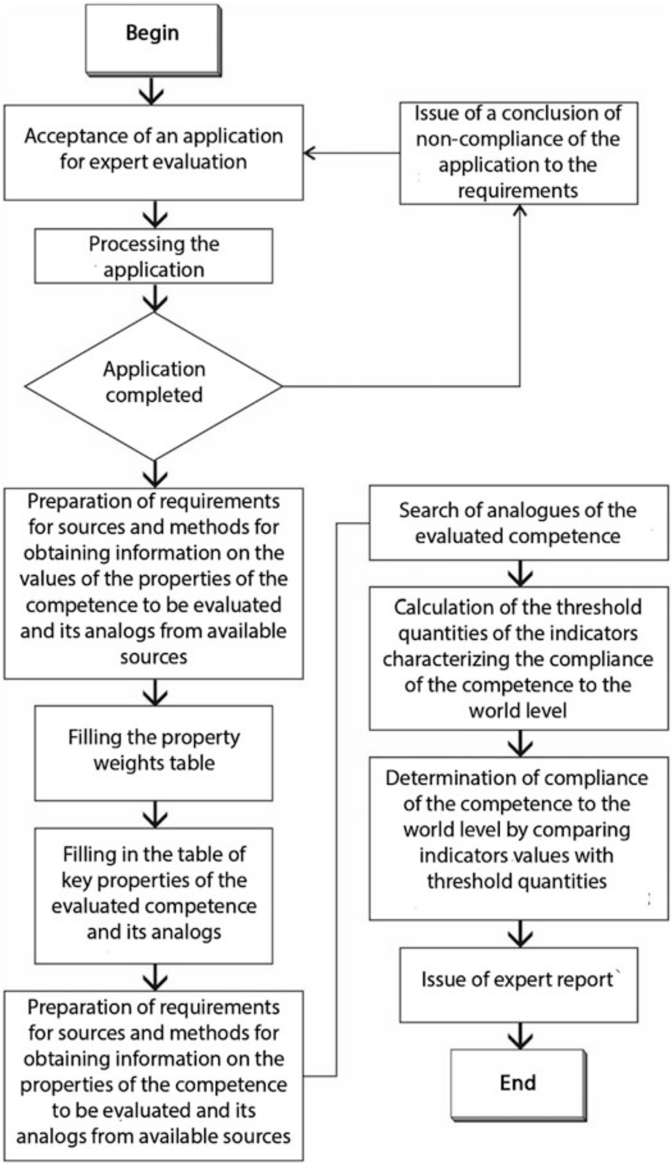

Fig. 5.6 Diagram of assessing the compliance of the competence to the world level

obtained information on the properties of the competence being evaluated and its analogs.

Stage 4. Determination of compliance of a competence to the world level and preparation of an expert report, including:

- Determining the compliance of a competence to the world level by comparing the values of the indicators of the competence (technology or products produced on its basis) with threshold quantities;
- Preparation of expert report.

(c) Determining the requirements for assessing the compliance of a competence to the world level, including:

1. Accepting and processing an application for expert evaluation. The document, the information card, in which all the required fields are completely filled, is registered as an application;
2. The application is analyzed for compliance with the requirements regulating the rules for filling in an application for expert evaluation. If the application does not comply with these requirements, an appropriate conclusion is issued;
3. In accordance with paragraph b.1 of the Algorithm, the requirements for sources and methods of obtaining information from these sources should be defined based on the information contained in the application for expert evaluation;
4. To determine the requirements for sources and methods for obtaining information on the properties of the evaluated competence and its analogs, experts whose competence relates to the same subject area as the technology being evaluated are invited to participate in the evaluation;
5. In accordance with the data contained in the application, a list of databases containing information that can be used to determine the parameters of the evaluated competence and its analogs is formed. Each database must contain information of at least one of the following types: information on fundamental research relevant to the evaluated competence or its analogs; information on applied research and development related to the evaluated competence or its analogs; information on the use of competence at the stage of industrial production.
6. Based on the information contained in the application, restrictions may be imposed on the publication date of information placed in the databases included in the list;
7. For each database, the requirements for methods and means of searching for data should be defined. The main search methods are search by patent classification headings and keyword search on texts and abstracts of documents, for which the classifier headings relevant to the evaluated object are determined, as well as requirements to the query's search image;
8. The International Patent Classification (IPC) is mandatory for use;

(d) Filling in tables of key properties and their weights:

1. Tables of key properties and their weights are designed to determine the properties of competences and their analogs, as well as the importance of these properties for evaluation purposes;

2. The right column of the key properties table contains the names of such properties of the evaluated competence and its analogs, the values of which can be quantified using measuring tools as a result of calculations or by obtaining values from experts;
3. The rest of the columns in the table contain the names of the parent property groups combining several properties from the next to the right column. Depending on the type of table, the left column should contain the name of the property that characterizes the quality or integral quality of the competence and its analogs. Depending on the requirements for sources and methods of obtaining information, properties can be determined either on the basis of classifiers of competences and their properties, i.e. on the basis of generalized and individual information, or on the basis of data on analogs. In the case of using generalized information to fill in the property table, the search for analogs of the competence is not obligatory. In the case of using individual information to fill in the property table, the search for analogs of the competence is obligatory.
4. Before performing the search for analogs, the requirements for sources and methods of obtaining information on the values of the properties of the evaluated competence and its analogs from available sources should be prepared;
5. The features of the search for analogs are contained in § 10;
6. Determining the weights (coefficients of importance);
7. Filling in tables of properties values and calculating threshold quantities of the indicators characterizing compliance of the competence to the world level;
8. To prepare the requirements for sources and methods for obtaining information on the property values of the evaluated competence and its analogs, experts whose competence relates to the same subject area as the technology being evaluated are invited to participate in the evaluation;
9. Search for analogs;
10. A list of analogs of the evaluated competence is compiled on the basis of the obtained information and materials; the list contains the properties of the analogs and the values of these properties. Among the found analogs of the competence are the following: analogs that are best for one of the properties to use information on them when determining the reference values of property indicators; analogs that are the worst for one of the properties to use information on them when determining the reject values of property indicators;
11. Filling in tables of property values is carried out for each property of the property table on the basis of information obtained from available sources (experts, documents and databases). The property values are specified for both the evaluated competence and all found analogs. Calculation of the threshold quantities of quality indicators and/or integral quality, characterizing the compliance of technology to the world level, is conducted in

accordance with The Analytic Hierarchy Process (AHP) by the following formulae:

Formula 1. Calculation of the normalized value of the property Kij is carried out according to the following formula:

$$K_{ij} = \frac{Q_{ij} - q_i^{\mathrm{ref}}}{q_i^{rej} - q_i^{\mathrm{ref}}} \tag{5.1}$$

where q_i^{ref} is the reference value of the property the table of property values of competence and its analogs;

q_i^{rej} is the reject value of the property from the table of competence properties values and its analogs;

Q_{ij} is the property value in a table of property values of competence and its analogs;

i ε {1...m} is the property number, where m is the number of properties;

j ε {1...n} is the competence or its analog number in the property values table, where n is the number of objects to be evaluated, including the evaluated competence and its analogs.

Formula 2. The formula for calculating the quality indicator or integral quality indicator

$$P_j = \Sigma \left(K_{ij}{}^* G_i\right) \tag{5.2}$$

where K_{ij} is a normalized indicator of the i-th property for the j-th evaluated object (competence or its analog);

G_i is a group coefficient of importance of i-th property in the last column (layer) for the j-th member; the coefficient for each group and subgroup of properties is determined with the help of AHP method using expert evaluations, here $\sum G_i = 1$;

i ε {1...m} is the property number, where m is the number of properties in the last column (layer) in the properties table;

j ε {1...n} is the competence or its analog number in the property values table, where n is the number of objects to be evaluated, including the evaluated competence and its analogs.

The threshold quantities of the indicators characterizing the compliance of the competence to the world level are determined as the maximum and minimum values of the quality indicator and/or the indicator of integral quality Pj of the world best analogs.

(e) Assessment of compliance of a competence to the world level:

1. Compliance of competence to the world level is established as follows: If the value of the quality and/or the integral quality indicator Pj of the competence to be evaluated is lower than the lower threshold quantity determined on the basis of information on the best analogs, then the evaluated competence does not comply to the world level. If the value of the quality and/or the integral

quality indicator Pj of the competence to be evaluated is within the interval determined on the basis of information on the best analogs, then the evaluated competence does comply with the world level. If the value of the quality and/or the integral quality indicator Pj of the competence to be evaluated exceeds the upper threshold quantity determined on the basis of information on the best analogs, then the evaluated competence is better than the world level.

2. Preparation of expert report.

5.3 Improving the Organizations Competitiveness on the Basis of Forming a Unified Industry Information Space for Technology Transfer

Information and communication technologies (ICT) are now an integral part of the world economy. ICT ensure the efficient world markets operation and acts as an engine for the dynamic development of all sectors of the economy, first of all, high-tech. In this regard, governments of many countries highlight the ICT direction as a strategic vector of economic development, the main source of accelerating economic growth at the present stage.

Currently, government bodies in many countries are actively involved in the development of ICT and the formation of an information infrastructure that will enable high-tech corporations to implement the strategy of open innovation and innovative technologies exchange in a certain sector and related industries. These processes are particularly relevant in the current context of the creating large integrated structures that are designed to reduce overall costs and focus resources on the key directions of development and promising R&D in order to improve competitiveness in domestic and foreign markets. Innovative processes in the economy are closely connected with the creation of new knowledge and mechanisms for their transfer between subjects of economic relations using the latest ICTs.

All large companies have organizational controls designed to manage the flow of knowledge. These controls are necessary to encourage the sharing of innovative resources and the transfer of knowledge both within the organization and beyond. In other words, organizations can manage the creation of new knowledge through monitoring and transferring existing knowledge. This applies to all forms of knowledge: individual objects of intellectual property, technology, non-formalized skills, experience and competencies.

In this regard, the problem of information exchange in high-tech corporations of science-intensive industries should be considered in three aspects:

1. The transfer of knowledge between the individual structures of the industry in order to intensify work in a specific field of activity. Taking into account that enterprises technologically related to different industries (rocket engineering, instrumentation, electronics, radio engineering, etc.) are involved in science-

intensive production, one can speak of an internal cross-sector knowledge transfer within the corporate enterprises system, which is possible only in conditions of formation and efficient operating of the sectoral information space;
2. Use of the organizations scientific potential for external technological transfer into related activities, including commercial ones. In this case, all the structural elements of the corporation, their research and production capabilities should be considered as a catalyst for innovation in other sectors of the economy, following the example of foreign countries;
3. Use of the international information space for the purpose of analyzing the world's innovative technologies, selecting the most promising and competitive ones and attracting those innovative technologies that can contribute to the competitiveness of high-tech products and achievement of the leading competitive positions in the world industry markets.

In this regard, the following algorithm for achieving world leadership is proposed, as presented in Fig. 5.7.

Consider in detail each stage of achieving leading competitive positions on the world market.

Formation of information bases and organization of technologies and competences transfer at the level of enterprises of the corporation At the first stage, it is necessary to solve the issue of creating information bases for technologies and competencies transfer within corporate structures. This stage in the overall system for achieving the leading positions is fundamental, as it is the basis for the further formation of industry competencies and innovation management centers. It is important that in relation to the object (enterprise/corporation) at this level of management, the transfer of technologies and competencies can be: internal—between the divisions of enterprises of the corporation; quasi-internal—the movement of technologies within the corporation, including between enterprises producing civil and military products; external—in relation to the enterprises of the corporation.

The formation of an information base that will ensure the systematization, ranking and finding the necessary technologies and competencies for application in a particular division of the enterprise and their distribution to the whole corporation is of great importance for the successful transfer of technologies and competencies.

In doing so, considerable attention should be paid to the format of the technology or competence description in the base. This format should be as detailed as possible in order to improve the transfer efficiency, which could significantly simplify the task of finding and speed up the process of the selected technologies and competencies implementation.

In general, we can distinguish the following main stages of technological transfer for the seller of technologies and competencies:

1. Technological audit, which includes expert evaluation of technology; marketing research of technology; finding new markets for the application of technology;

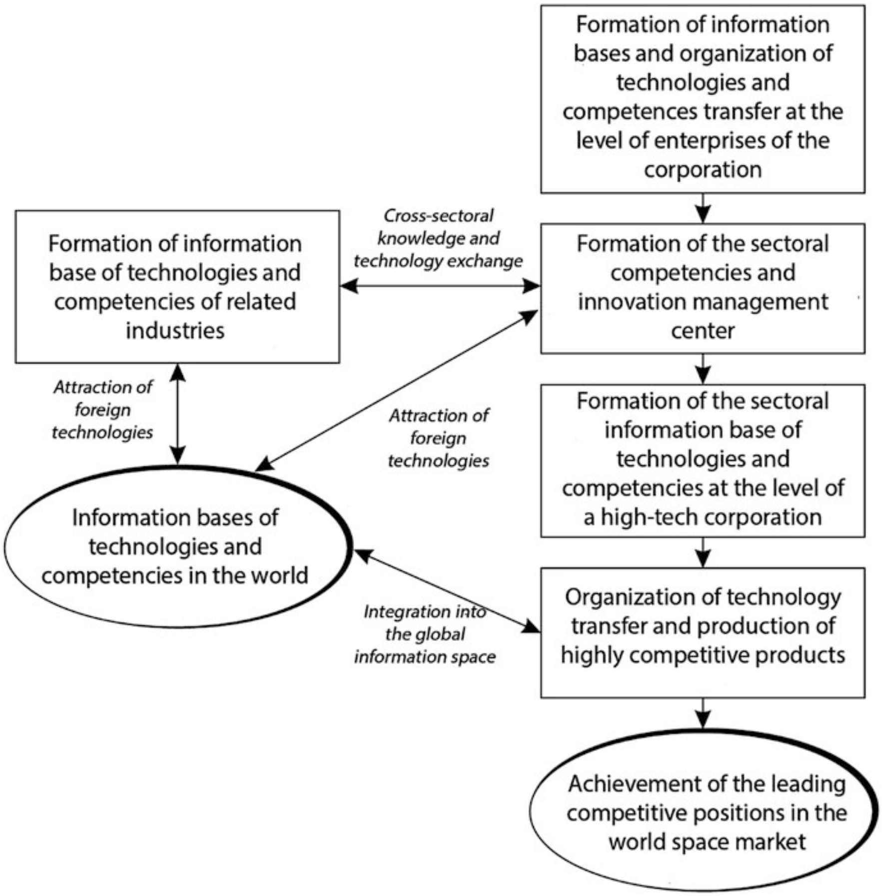

Fig. 5.7 Stages of achieving leading competitive positions in the world space market. Source: Compiled by authors

assessment of the opportunities of commercialization of technology; the development of a technology transfer strategy;
2. Preparation of materials in accordance with international standards for the presentation of technology;
3. Consulting and legal support: consulting on the intellectual property protection; development of optimal forms of technology/competence transfer; legal registration of technology/competence transfer.

When organizing external technology transfer, the manager is faced with the question of whether it is expedient to use own developments or would it be advantageous to attract them from outside. The rejection to use the external transfer is appropriate in case of a threat of loss of technological and economic independence of the organization. Such a situation can arise in the case of the purchase of a key technology or the main nodes from a foreign supplier.

The main problem of financing projects for the competencies development seems to be the absence of funding mechanisms. The implementation of most projects is related to the training of personnel, production, infrastructure, and this is provided for by the corresponding budgetary items of expenditure. Projects do not provide for special expenses for creating competencies.

High-tech industry usually creates technologies and related competencies for solving narrow tasks of state order; they are not a complete product suitable for commercialization and transfer to related industries. Moreover, the possible civilian application of dual technologies is often beyond the understanding of the developer, and he expects a counter initiative, proposals for possible adaptation of the product to a new field of application. The same applies to competencies, where the initiative should come from the acquirer. The organization's ability to operate successfully in one of the directions indirectly implies the possibility to successfully carry out related activities also.

Competencies pass through several stages in their development, before they turn from basic to core category. Formation of a core competence is possible only after the creation of technology, the release of finished products and its successful sale in the market, which is a sign of competitiveness. The transfer of competencies should be proactive to stimulate innovative development. Such a mechanism will facilitate the development of a transfer of competencies and scientific and technical cooperation between all enterprises of a high-tech corporation.

Formation of information base of technologies and competencies of related industries The long-term goal of knowledge transfer is to support economic growth in the foreseeable future through the development and commercialization of new technologies. In the global economy, the nation's wealth directly depends on its competitive position in the global high-tech market, which cannot be achieved by superiority in the narrow market segment (for example, in the rocket industry), but requires the development of the potential of all sectors of the economy.

For this reason, the problem of knowledge transfer can not be limited to the departmental boundaries of one industry, but it must include an external component with the goal of achieving a leading competitive position in the world market. In this regard, it is necessary to create information bases of technologies and competencies in all high-tech industries with a view to organizing the cross-sector transfer that ensures the reduction in the amount of resources required for the production of innovative products and the improvement of their competitiveness.

Formation of the sectoral competencies and innovation management center An industry structure should be established in the high-tech sectors, which would control the following issues:

- Legal assistance to enterprises in the transfer of any knowledge;
- Assessment of the status of transferred knowledge in terms of state secrets, the formation of a list of dual technologies that allow civilian free use;

- Formation of technological competence and databases;
- Examination, assessment of the significance and prospects for the use of competences and issuing recommendations on their allocation in the enterprises of a high-tech corporation;
- Economic estimations to choose the most efficient way of transferring competencies between specific enterprises;
- Identification of technologies and competencies that ensure import substitution and their inclusion in enterprise development programs.

Formation of the sectoral information base of technologies and competencies at the level of an industry or a large corporation Implementing the processes of identifying competences, the competencies and innovation management center based on the application of ICT should form an appropriate information base containing full information on the existing achievements of enterprises of a high-tech corporation. The technologies databases have long been applied in world practice (e.g. NASA NAFCOM and SpinOff). At the same time, it is possible to link technologies in these databases with core competencies necessary for their creation and application. This will give the possibility to improve the efficiency of technology transfer. It is logical that companies with the necessary competencies should become potential consumers of technologies. Then the innovation process will be much more efficient. Competencies determine susceptibility to innovations, the use of this ability allows quick learning from others' experiences and copying perspective designs. This seems extremely important in the face of economic sanctions and the need to implement import substitution programs.

Competence, in turn, cannot be considered in isolation from the overall system of knowledge management. Competencies (abilities) are always associated with resources, intellectual property and other knowledge. Hence the need for a knowledge management system; competencies constitute one of the categories of information resources.

The identified knowledge is an information resource; it can be divided into three types: data, information, competencies (knowledge, abilities).

Here, data will be understood as facts, indicators and values that are uniquely determined by a fixed set of measurements. For example, the fact is the time and cost of implementing a project, the laboriousness of a particular operation, etc.

Information is a formalized text that describes the properties and technical characteristics of the objects being analyzed. Information is the semi-structuring of data that may be relevant to the problem being solved. For example, this is a textual description of the technology with highlighting the keywords, using which we can choose technology for a particular task. The information is a description of the properties and technical characteristics of materials, parts and other items, processes and so on.

Competencies are a synergistic system of knowledge, rules, regulations, methods of achieving certain goals and objectives. This knowledge provides the organization's ability to solve certain tasks and is a necessary condition for efficient activity.

Competences are the result of processing information; they have their own scope of efficient application and a long life period.

Data is the simplest type of information resource. The data store is a hypercube that systematizes data in terms of organizational subjects, personnel, objects, processes, and time. Various facts (indicators) are used as storage object values: cost, laboriousness, resource intensity, production volume, number of employees involved, quality control data, standards used, etc.

Information storage is also organized in the form of a hypercube, and all basic measurements are saved in it as in the previous case, but its content usually is represented as a text.

Of greatest interest is the third hypercube, which contains competencies in the form of documented procedures for the implementation of processes, techniques, instructions and methods for solving problems. The main problem is that competence is not synonymous with a certain technique or skill, it gives the possibility to efficiently solve a wide range of close problems, and therefore, simultaneously refers to several processes, methods, etc. In these cells, the data cube stores knowledge frames.

The knowledge storage structure in the data bank is presented in Fig. 5.8.

In the "Data" hypercube, the knowledge has its unique place with reference to the corresponding process, subdivision, resource, etc.

In the "Information" hypercube, the same knowledge can refer to different categories (dimensions), i.e. repeatedly duplicated in the cells of the hypercube.

Finally, competencies cannot be unambiguously tied to dimensions at all. This process is dynamic when some knowledge, originally tied to certain dimensions (usually on the fact of main usage), can be tied to other knowledge by entering the relevant data into slots. For example, the fact of access to some information when searching for the keyword "nanotechnology" means the existence of a connection of this competence with all processes, equipment and other assets related to nanotechnology. This approach has become well-known to Internet users today, when after search queries they receive advertising information on the topic of this request for a long time.

Using multidimensional cubes technology allows obtaining Points-of-View in any dimension and to receive simultaneously information on data, information and competencies.

Organization of technology transfer and production of highly competitive products The principal difference between the external cross-sectoral transfer from the internal one is the need to organize efficient control over the use of innovative technologies and other achievements in private interests, which can potentially pose a threat to the state interests.

The main problem that prevents the efficient use of many innovative developments is their close connection with the economic security of the state, the defense capability and global competitiveness of strategically important sectors and the economy as a whole. These knowledge and technologies can contribute to the development of a wide range of high-tech enterprises, ensure a sustainable economic

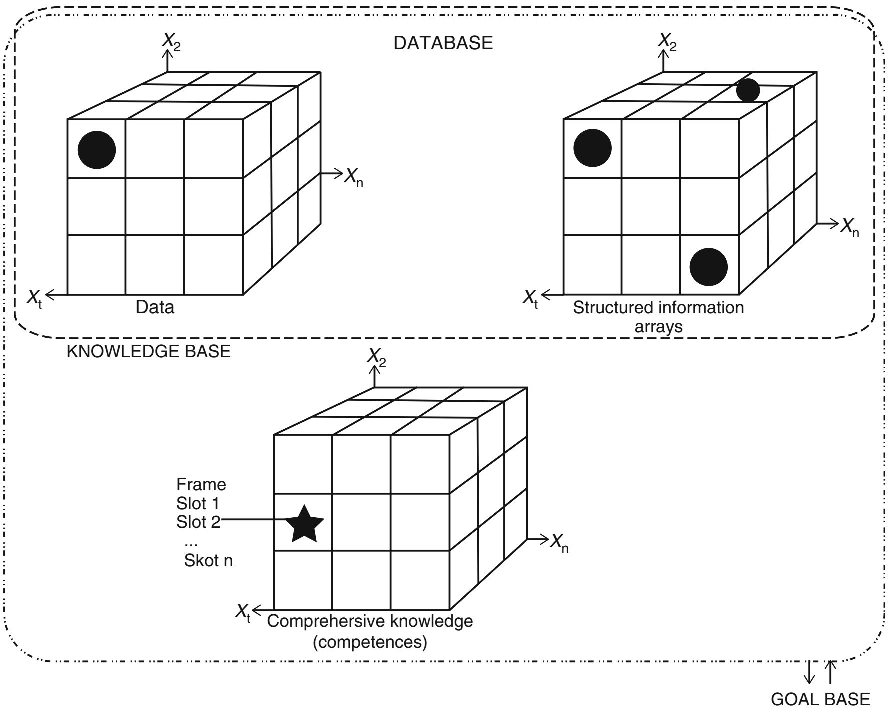

Fig. 5.8 The knowledge storage structure in the data bank. Source: Compiled by authors

position, and bring high revenues to the state budget. On the other hand, the spread of such unique knowledge and technologies can be dangerous, therefore such knowledge is subject to special state control.

In order to use the results of innovation, the most efficient way is to improve the policy of information exchange in high-tech sectors in the following directions:

1. *Technology transfer through diversification of activities.* Transfer of knowledge and innovative technologies in a high-tech corporation can not be considered solely from the position of state departments. In any economy, there is a need to ensure the transfer of knowledge, technologies and achievements to related industries in the form of diversifying the corporation's structures activities, transferring technologies to private companies, implementing joint projects using core competencies of the corporation's enterprises and in other ways. Since the transfer of technologies and competencies is related to the issues of their protection against unauthorized use, a revision of the concept of this protection is required. It must be transformed from the protection of departmental interests to the idea of a general industrial state defense of the, where high technologies play a key role;
2. *Resource optimization with the help of the competencies and innovation management centres as the industry integrators.* The issue of information exchange

within the framework of state programs implementation most often covers the interests of several participating companies, both public and private. The identification of mutual interests can be carried out based on an estimate of the cumulative effect within the aggregate costs concept. This approach allows solving the optimization task of project management with the playback of various scenarios.

The same can be said about the organization of production. The independent use of a technology gives for the owner of the technology the possibility to develop the production capabilities. On the other hand, the organization of production at another specialized enterprise with larger production capabilities, a more convenient geographical position and better human resources may be advantageous.

Optimization task of this kind can be solved only with the organization of the centralized program management, involving representatives of all participants, by joint efforts.

3. *Improving efficiency through the creation of a licensing system.* The contradiction between the economic feasibility of using many defense technologies in the civil sphere and the need to preserve state control over key technologies is traditionally solved through technology transfer licensing. This forced but necessary procedure largely determines the possibilities and efficiency of technological exchange. On the one hand, it must guarantee the preservation of state secrets, on the other, promote the technologies developers efficiency growth and the state scientific and technological capacity.

Today, the practice of innovative technologies management in high-tech industries in many countries needs to be improved. The obstacle to the enterprises sustainable development is the lack of a clear regulation of the commercialization of innovative technologies and the intellectual activities results. Managers often refuse to sell technology even to domestic private partners, as they may face the problem of classifying these technologies as state secrets. However, the use of intellectual property as a share in the company's authorized capital is a common practice in many advanced projects.

The solution to these contradictions can be achieved through the establishment of an efficient licensing system. This system should be clear to the management of the enterprise, the approval for transfer "from on high" should give the company freedom of action within the established framework. It is logical to divide all partners into categories to reduce bureaucracy in the transfer licensing.

The first category will be integrated corporate structures. The technologies transfer between them is the internal transfer; it is determined by departmental regulations and must be carried out as quickly as possible. There is no need for special permits, since all enterprises are known to be classified units. The basic premise here is research and production expediency.

The second category consists of the most trusted external to the corporation partners. Today, high-tech corporations can not do without attracting private companies, respectively, it will be necessary to jointly solve production and technology issues. In addition, private structures implement commercial projects related to the alternative use of technology more efficiently. The large amount of information transferred in such Public-Private Partnership projects makes the state licensing procedure unnecessarily time-consuming. It is extremely difficult to control all these elements. Therefore, the technology monitoring should be simplified: it is necessary to shift control from the technology itself to checking the integrity of its recipient. Abundance of caution contradicts the principles of successful business. The key point of working with long term partners is trust. Hence the technology transfer itself is not the subject of control, but the nature of its further use is. Such agreements can be both bilateral and multilateral, when participants in a common project enter into an agreement on long-term cooperation.

Finally, there are other contractors in any project. As a rule, these firms are involved for the project period to solve a narrow problem. It is not possible to verify their integrity in full, and control over the transfer of information on key technologies should be held on a general basis, which does not negate the need for the fastest possible transfer applications consideration;

4. *Systematization, monitoring and management through the formation of information databases.* Regulation of knowledge exchange processes involves the creation of a database on existing achievements. In many countries, there is a list of key technologies that determine national and economic interests; the transfer of such technologies requires special security arrangements and control by state bodies. This list is a formal basis for the prohibition of transfer, but it has significant shortcomings. The list should be kept up to date. Today it is important not only to control potentially dangerous technologies, but also to have a list of technologies that develop science (like British DSTL-list). It is important to understand which competencies contribute to the creation of such technologies. Control over these competencies will prevent their development by competitors.

The implementation of measures on the above main directions for improving the policy of information exchange (between enterprises and industry corporations, related industries and foreign organizations) will contribute to a possible reduction in the innovative production costs or the creation of innovative technologies based on existing ones that allow increasing competitive advantages, thereby achieving leadership in the world market. In turn, foreign market players may take an interest in acquiring our innovative technologies, the data of which will be provided to them through information exchange between the national competencies and innovation management center and foreign centers. Thus, as foreign experience shows, sectoral competencies and innovation management center is integrated in the global information space. This space is the basis for competencies and technologies exchange between the key markets players in the framework of the national high-tech corporations open innovation strategy implementation by and ensures organizations competitiveness.

Chapter 6
Pricing Management Taking in Account the Core Competencies for High-Tech Industry Sustainability Support

6.1 The Influence of Competencies on the Price and Quality of Products

In the current rapidly changing market situation, especially in the context of the financial crisis, a change in the price of suppliers for materials and components, a change in the tariffs of natural monopolies may lead to the fact that manufacturers with a long production cycle will not be able not only to obtain the desired profit, but also may be in a situation where revenue does not cover production costs.

Best prices for goods and services are an important competitive advantage of the organization. Therefore, they can be considered as one of the tools of a market competition. The analysis of competitors prices for goods and services can help in establishing own market pricing policy: prices over the average market level; prices below the average market average.

Here the average market price level for similar goods is of key importance. To determine this level, it is necessary to take into account not only the state of affairs in a particular product line group, but also the influence of inter-product, sectoral and cross-sectoral competition. Therefore, the average market price level is the result of an analysis of a large heterogeneous factors group under conditions of relative uncertainty of these factors (e.g., relative demand, size of the market) and the market processes in general.

The market price of the goods (works, services) is the price formed by the interaction of supply and demand in the market of identical (if not available, then homogeneous) goods (works, services) in comparable economic (commercial) conditions. Also, the market price is interpreted as the price that satisfies both the seller and the buyer of products and is the result of their free will when concluding contracts with each other.

Methods of price competition can be divided into three groups. The first group consists of methods based on lowering the prices, the second of methods based on

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prices increase, the third one consists of methods based on maintaining prices at a constant level.

Price competition can have an objective and subjective platform. The subjective platform of price competition is that these groups of competitive actions methods are applied under the influence of different competitive targets.

Lowering prices below the average level is used in that case, if the organization intends to:

– To attract consumers and suppliers with a new stable competitive advantage in the form of relatively low prices;
– Maintain relatively low prices and thereby maintain the previously achieved competitive advantage;
– Temporarily or finally withdraw from the competitive area, go to a significant price reduction to quickly leave this area of business, sell the business;
– To conduct a dumping campaign and drive out competitors from the market due to the availability of price resources;
– Simulate active actions in a particular market segment against the background of maintaining unchanged or even increased prices for goods/services offered for other market segments;
– Use relatively low prices in a situation when it is not possible to determine the average market price level for identical goods due to the fact that the market itself is not formed.

Prices increase over the average level is applied when the organization intends to:

– Implement certain actions and attract consumers and suppliers by relatively high prices and nonprice competitive advantages, real or imaginary;
– Simulate active actions in a particular market segment against the background of maintaining unchanged or even lowering prices for goods/services offered for other market segments;
– Carry out certain actions in hope to maintain some specific market segment, accustomed to bear considerable costs for the sake of satisfying the needs;
– To carry out sudden actions in the face of force majeure. For example, this occurs in a well-known form of speculation on the wave of a sudden short-term feverish demand;
– Stick to isolationism and defiantly appoint or maintain high prices.

The objective platform of price competition is that these competitive actions methods groups are applied under the influence of changing pricing factors. The objective basis for lowering the price is always the relative reduction of the organization's costs per unit of consumer value (useful effect) of goods and services.

The objective basis for prices increase is also the relative reduction of the organization's costs per unit of consumer value (useful effect) of goods and services. The increase in prices is an objectively conditional phenomenon when an absolute growth in the costs of the organization takes place. However, it can be considered a method of competition only in the case when the absolute growth of costs of the organization is accompanied by a relative reduction in costs per unit of useful effect.

A simple increase in prices indicates a decrease in competitive advantages of the organization. At the same time, an increase in prices accompanied by an improvement in the products quality through the active use of existing core competencies or the achievement of other competitive advantages can be viewed as an indicator of increasing its value in the consumer's eyes. Proof of this is the fact that the organization realizes its products, it enters into the value chains in conditions when the prices for these products are higher than the average market level.

If growth in costs does not result in price increase, the organization is guaranteed to incur losses. If the increase in prices is accompanied by a relative reduction in the organization's costs per unit of useful effect, the organization actually increases its profit without losing its clientele.

The correlation of the objective and subjective platforms is an important indicator when choosing the instruments for competitive actions. Overstatement of each of them is very dangerous. Meanwhile, the optimal balance between them helps to establish a reasonable level of intensity and sustainability of competitive actions.

The impossibility of an objective justification of the high-tech science-intensive product's price in the present and in the future (for a long-term contract) is the reason for concluding a contract at a fixed price for several years or a contract with agreed option of price changes in a small range (up to 10%) or contracts within which the manufacturer has no right to change the price significantly.

This is due to the fact there are no valid pricing methods which would take into account the price change on a long run with a given accuracy, also taking into account the manufacturer's technological features (the internal functioning, the impact of market conditions and prices on materials and components).

The currently used producer price index by lines of business is a rather generalized indicator and it is unlikely to ensure a sufficient convergence between the real and predicted values; this will significantly affect the estimated level of profitability, both in the direction of its overstating and in the direction of understating. In this regard, it is necessary to calculate and use more differentiated price indices.

The industrial producer price indexes are used for studying and characterizing price processes in the economy, comparative analysis of price changes for products of certain industries, revaluation of fixed assets, privatization, revision of rent rates, indebtedness indexation. The determination of such indices is carried out in accordance with the Methodological guide for monitoring industrial producer prices and developing producer price indices. The industrial producer price index (PPI) is calculated on the basis of registered prices for representative goods in basic industrial bodies. The PPI is used when performing various economic calculations and forecasting at the macro level, for estimating the industrial production volume in constant prices, gross domestic product, etc.

PPI development consists of the following stages:

- Selection of representative goods to be included in PPI development;
- Selection of basic industrial bodies for price monitoring;
- Determination of the procedure for registering and collecting price information;

– Selection of a weighting system for the calculation of aggregate price indices for various levels of aggregation;
– Selection of the formula for calculating the PPI.

Selection of representative goods Representative goods are understood as an aggregate of certain types of goods in the commodity group, which may differ from each other by minor features that do not affect the quality and basic consumer properties of goods, and are homogeneous in their utilitarian purpose.

Type of goods—a specified minimum unit of goods, which has certain characteristics, properties, specifications and attributes.

The commodity group is an aggregate of homogeneous types of goods.

Selection of representative goods for price registering is carried out for two purposes:

– Determining the average producer prices for certain types of representative goods;
– Calculation of producer price indices for selected types of goods and calculation of composite price indices for commodity groups, sectors and sub-sectors of industry, economic classes (broad economic categories), and industrial production as a whole.

The main principle of selecting goods for price registration is the representativeness of the selected types to characterize the price dynamics of commodity groups, sectors and sub-sectors of the industry in a region and in Russia in a whole.

Note that when forecasting prices with a given accuracy for a particular industrial organization's product, it is inappropriate to consider the average prices of producers selected for registration administratively. First, the average value of the indicator (in this case, prices) does not take into account such significant factors of price change as: market factors affecting the price changes (exchange rates, tariff rates, etc.); the permissible prediction error (depending on the organization's objectives, the error may vary, but the averaged data do not reflect the dynamics of the purchase prices on materials and components); deviation from the average producer prices (which characterizes the market and is a significant indicator in forecasting the market situation).

Let us consider in more detail the methodology for calculating the PPI. The basic assumption of the producer price index methodology is that the change in prices for the types of goods selected for monitoring and goods not in the sample but still being products of the same commodity group are alike both in this organization and in others not selected for the survey.

The selection of goods for the prices registration is carried out in stages by the directional sampling. The list of representative goods and commodity groups necessary for calculating the PPI is formed centrally.

When calculating the PPI, the only one factor taken into account is the inflation, whereas the number of factors directly or indirectly affecting the price level is much larger (exchange rates, refinancing rate, change in duties and taxation, etc.). In addition, the formation of a sample of producer prices for goods in the list is usually carried out after a certain period of time, whereas in a financial crisis, for example, the price dynamics may be unstable, either ascending or descending. These changes are usually recorded within the organization. Such records are necessary for an objective assessment and forecast of the price and all (or most significant) parameters forming it.

There are several basic methods for price estimation to ensure the continuity of the index series:

1. Use of the relative change in prices for similar goods.
2. Use of the average price change for the commodity group, which includes the temporarily disappeared representative goods.
3. Using an average price changes in a sub-sector, a local sector.

Calculation of individual and composite industrial producer prices indices Price indices calculation can be made with the use of one of two methods, the basis or the chain one:

The basis method supposes bringing the current month registered price to a constant basis price. The price for a particular type of goods for any month chosen as the basis (e.g. December of the previous or any previous year) may be accepted to be the basis price. The monthly price index for the basis method is determined by dividing the current period basis index by the basis index of the previous period. As a rule, the basis method is used when fixing prices for products to be produced continually for several years in a stable economy.

The chain method is more common; here the monthly index is determined by comparing the price of goods in the current month to the price of same goods in the previous month. The chain index for a long period of time is determined by multiplying monthly price indices. Usually, this method is used in a case of unstable production, frequent changes in the types and the quality of products.

Note that both these methods do not take into account the impact of individual market pricing factors. Moreover, the outlined methods do not take into account the pricing of materials and components suppliers (price policy, output volume, contractual obligations, delivery terms and shipping costs, etc.) which is necessary for forecasting changes in the products price. In addition, it is not possible to take into account the degree of influence of this or that factor on the formation and change in the price of the product, as well as the change in the degree of this influence. Within the methods considered, the price of a product is seen as a final indicator without regard to the price structure, its changes, the internal and external environments factors, the influence and changes in this influence of those factors, and their interdependence. Of course, this affects the accuracy of the forecast of the price and the costs forming the price.

The classification of the main high-tech production pricing factors is given in a general form in Fig. 6.1.

Price is the most important tool of entrepreneurial behavior, a kind of signal that can quickly perceive and take into account local and foreign competing companies.

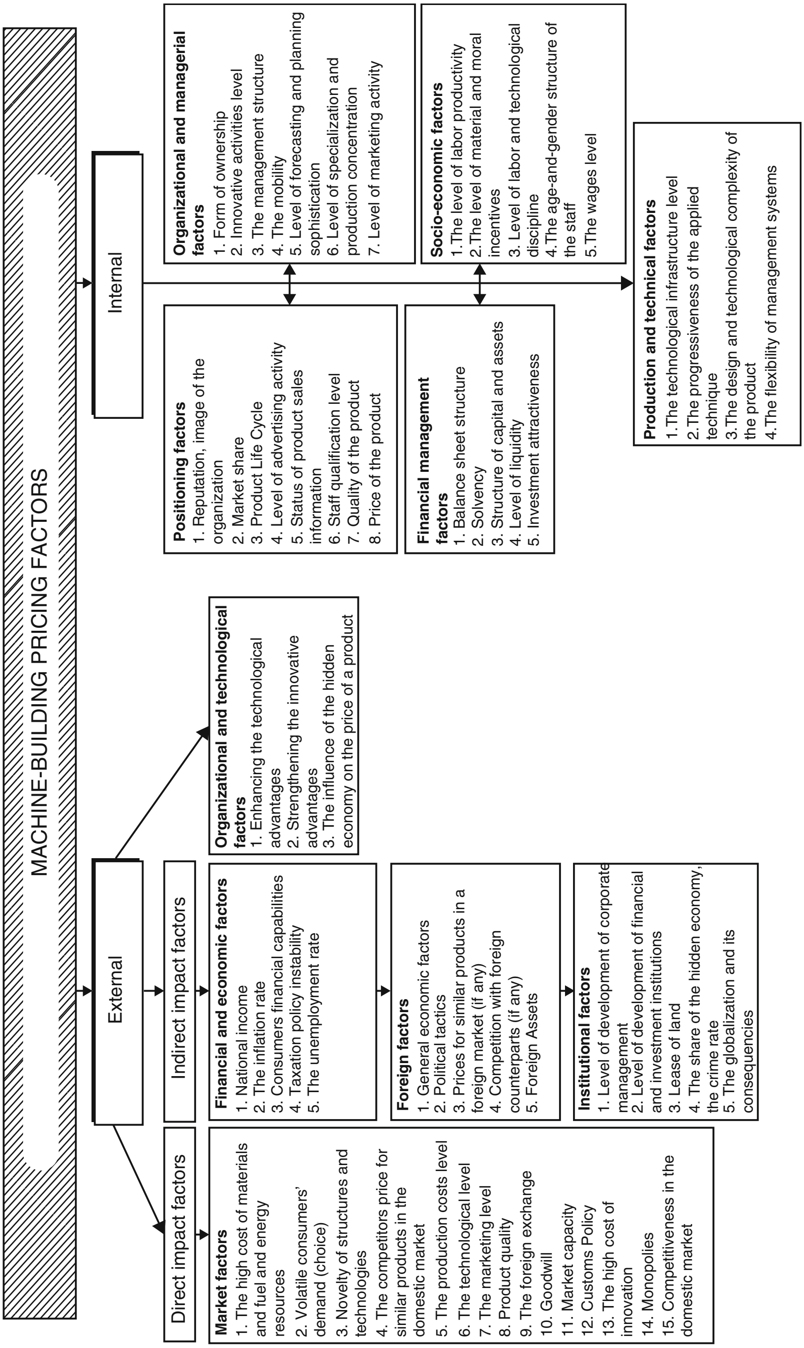


Fig. 6.1 Classification of the main high-tech production pricing factors

This is why many companies consider the issues of pricing and the choice of a price line when conducting import-export transactions as confidential information. However, despite the importance of price decisions for foreign markets, they are often tactical rather than strategic in nature or are a response to the price behavior of competitors.

The company's effective pricing strategy should be something more than a reflection of market conditions. Any pricing decision should reflect: the fundamental price strategy of an international corporation, market segmentation, the elasticity of the market, the costs for promoting products to external markets, the capacities of competing local and foreign producers.

Modern foreign markets are characterized by a wealth of different sectoral goods and services and differentiated prices for them.

Actually, there are three groups of price strategies used by companies in external markets:

- Pioneer;
- Standard;
- Adaptive.

The pioneering and standard price strategies differ on the basis of the following mark features: while the first group of strategies deals with pioneering goods or their essentially modified designs, the standard price approaches are used for the entire product range sale. The companies are free in making price decisions in both cases.

The adaptive price strategies are typical for companies copying competitors' price policy, up to a sign.

At the same time, each international company implements both standard and individual approaches for determining the structure and level of the optimal price in a particular country. This price is influenced by such factors like the technical production level, the costs, labor productivity and the competitive advantage created while design and manufacture.

Experts on the issues of the costs and prices formation in the export production of the United Nations Conference on Trade and Development (UNCTAD) International Trade Center suggested a number of alternative pricing methods:

- Pricing on the production costs basis: full costs and marginal costs methods;
- The break-even method;
- Bringing the price to the demand price level;
- Foreign trade competitive pricing method.

Defining the price (justification of the transaction price) may be done using different methods; but the statistics shows, most of them do not take into account many factors (besides the inflation) associated with a possible change in the price of science-intensive products with a long production period in the scope of a long term partnership.

In this regard, we will calculate prices using the apparatus of mathematical modeling and forecasting, and taking into account the influence of external and internal factors.

The mathematical model for determining the price of products belongs to the class of multifactorial models, since the price of a product depends not on one but on a number of parameters.

The mathematical model for determining the price of products is as follows:

$$\left.\begin{array}{l} C = (x_1, \ldots, x_k); \\ S = S\big(D_i, Rp_j, K_l, e\big); \\ h = h(z_1, z_2, \ldots, z_m); \\ P_S = Ps(p_1, p_2, \ldots, p_n); \\ P = P(C, S, h, Ps), \end{array}\right\}, \tag{6.1}$$

where C is the cost of the product;

x_1, x_2, …, x_k are the cost's components, from 1 to n;

S is the demand for the product in terms of money;

D_i is the i-buyer's demand for this product in terms of money;

Rp_j is the j-th buyer's demand for this product in terms of money;

K_l is the demand for the l-th competitor's product in terms of money;

e is the demand elasticity;

h is the change in selling price due to the inflation;

z_1, z_2, …, z_m are the external factors affecting h;

P_S is the reference price;

p_1, p_2, …, p_n are the prices for similar products of competitors in the market.

Within the considered methodology, it is necessary to determine the change in the parameters structure affecting the pricing, depending on their relative weights. To do so, we should assign appropriate weights to each independent model parameter to determine its η-weight in forming the dependent variable.

If this weight is not lower than the specified η * ($\eta\ (\rho) \geq \eta$ *), the independent variable within the framework of the proposed model should be investigated in detail.

Besides that, it is necessary to build the autoregressive function, i.e. regression function that reflects the dependence of the variable on its own earlier values, for all independent variables which meet the $\eta(\rho) < \eta^*$ condition. This function will allow forecasting the variable and its derivable variables, and the price of the product seen as the final calculation value.

Virtually this model is realized with the use of the recursive digital filter of the p + 1 order, known as the infinite impulse response (IIR) filter.

For practical purposes, the model (6.2) is applied:

$$\left.\begin{array}{l} C = C(x_1, \ldots, x_k); \\ x_1 = x_1\left(q_1, \ldots, q_{nq}\right) \quad if \eta(x_1) \geq \eta^*; \\ x = x_2(w_1, \ldots, w_{nw}) \quad if \quad \eta(x_2) \geq \eta^*; \\ x_3 = x_3(r_1, \ldots, r_{nr}) \quad\quad if \quad \eta(x_3) \geq \eta^*; \\ x_6 = x_6\left(g_1, \ldots, g_{ng}\right) \quad\quad if \quad \eta(x_6) \geq \eta^*; \\ x_{10} = x_{10}(v_1, \ldots, v_{nv}) \quad\quad if \quad \eta(x_{10}) \geq \eta^*; \\ S = S\left(B_1, \ldots, B_{14}, Rp_j, K_l, e\right); \\ h = h(z_1, z_2, \ldots, z_m); \\ P_S = Ps(p_1, p_2, \ldots, p_n); \\ P = P(C, x_8, Vr, n, Np, S, h, Ps). \end{array}\right\}, \tag{6.2}$$

where $q_1, \ldots, q_{nq}$ is the breakdown of the materials and components costs;
nq is the number of variables $q_1, \ldots, q_{nq}$ in the *breakdown list*;
$w_1, \ldots, w_{nw}$ is the fuel and power costs breakdown;
nw is the number of $w_1, \ldots, w_{nw}$ in the breakdown list;
$r_1, \ldots, r_{nr}$ is the shipping and handling expenses breakdown costs;
nr is the number of $r_1, \ldots, r_{nr}$ in the breakdown list;
$g_1, \ldots, g_{ng}$ shipping and handling expenses breakdown costs again, but whereas
ng stands for the number of $g_1, \ldots, g_{ng}$ in the breakdown list.

Thus, the dependent variables are on the left side of the equation, while the right side (the data in parentheses) contains independent variables.

Let us design a mathematical apparatus that describes the functional dependencies coming from the above (6.2) model, which dependencies take into account all the data necessary for the practical calculation of the product price.

This apparatus originally is intended for the short-term pricing under the conditions of an uncertainty. The price would depend on the (6.2) conditions.

Within the above technique we suggest the use of a regression model to establish a functional correlation between the dependent variable (the system response) and independent factors of the equations in (6.2). The analysis stages are as follows:

1. Determining the functional correlation type

   Establishing the type of correlation between the dependent and independent variables: the choice of the multiple regression model form may be based on the chosen hypothesis about the nature of the relationship between the observed variables, the type of their correlation (linear, nonlinear), their distribution functions (polynomial, power, exponential, etc.). The guidelines for finding the correlation types is the economic content of the problem being solved, as well as the behavior of other indicators observed.
2. Bringing the model to the linear form.

   The linear dependence form like ($y = b_0 + b_1x_1 + \ldots + b_kx_k$) is the most common for econometric studies.

   Anyway, if a nonlinear curve, we approximate it and bring to a linear form.

There are standard linearization methods, incl. logical linearization of the original data. Among them:

- Logarithmic approximation using the ($Y = AX^b$) formula;
- Semi-logarithmic ($ln(Y) = b_0 + bX + e$), or ($Y = b_0 + b_1X + e$) approximation;
- Inverse-logarithmic ($Y = b_0 + b_1/X + e$);
- The exponential function ($Y = b_0e^{bX}$).

When developing the multiple linear regression (MLR) model, it is necessary to take into account all the factors; there are certain verification methods and ways to transform the initial data into a satisfactory form:

(a) The regression errors expected mean is zero: $M(e_i) = 0$;
(b) Homoscedasticity (the homogeneity in terms of approximation errors variance): $D(e_i) = D(e_j) = \sigma^2$ for any i, j;
(c) No autocorrelation errors: e_i and e_j are independent if $i! = j$ (i is not equal to j);
(d) Random variations do not depend on explanatory variables: $\sigma_{e_i x_i} = 0$;
(e) We are dealing with a linear model;
(f) No multicollinearity, i.e. there is no direct correlation between independent explanatory variables (x_i);
(g) All the e_i errors are normally distributed. This makes sense for statistical hypotheses only.

If one of the prerequisites is not met, the resulting multiple linear regression may be not objective enough, due to accumulating the error.

There are data adjustment methods for the cases when the mathematical model does not meet the above requirements:

(a) Check the chosen type and parameters of the model;
(b) Methods to mitigate problems of heteroscedasticity;
(c) Methods for eliminating the autocorrelation;
(d) Check if the given conditions are crucial for the chosen econometric model;
(e) Model linearization methods;
(f) Methods for eliminating multicollinearity (the exclusion certain variables from the model, choosing some other type of a mathematical model, etc.).

3. Building a multiple linear regression model.

   Multiple linear regression has the form:

$$\widehat{y_i} = b_0 + b_1x_{1i} + b_2x_{2i} + \cdots + b_mx_{mi}, \tag{6.3}$$

where $\widehat{y_i}$ is the simulated value of the dependent variable (the system response) of the regression model;

x_1, x_2, … x_m are the values of the independent variables (factors) of the regression;

i is the number of the observation in which the value of the variable was determined (for example, the number of the month or quarter of the price determination when consecutive numbering);

$b_0, b_1, b_2, \ldots, b_m$ are the required regression coefficients for which the dependent and independent variables satisfy the regression equation.

As a rule, individual values of economic data do not fit exactly to a straight line or to another smooth line; it is not always possible to choose $b_0, b_1, b_2, \ldots,$ such that independent and dependent variables satisfy (6.3) for all i.

Therefore, the equation of the form (6.3) is often inadequate for economic measurement purposes. This problem is overcome by introducing into the relation (6.3) the stochastic term (error parameter) e_i, which is the deviation of the response value simulated by the regression from the real value. Then a linear multiple regression equation for real response values takes the form:

$$y_i = b_0 + b_1 x_{1i} + b_2 x_{2i} + \cdots + b_m x_{mi} + e_i, \tag{6.4}$$

where y_i is the real value of the response in the i-th observation;

$e_i = y_i - \widehat{y}_i$ is the deviation of the simulated response value from the real one (regression error).

Equation (6.4) is a linear regression model (or a linear regression dependence of y from $x_1, \ldots, x_m$). If we have samples of $Y = \{y_i\}$ and $X = \{x_{1i}, x_{2i}, \ldots, x_{mi}\}$, $i = 1, \ldots, n$, where n is the number of observations of the variable Y, X (i.e. the number of quarters (months in which the original data values were produced), then the mathematical model (6.4) can be rewritten as:

$$\begin{aligned} y_1 &= b_0 + b_1 x_{11} + b_2 x_{21} + \cdots + b_m x_{m1} + e_1; \\ y_2 &= b_0 + b_1 x_{12} + b_2 x_{22} + \cdots + b_m x_{m2} + e_2; \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ y_n &= b_0 + b_1 x_{1n} + b_2 x_{2n} + \cdots + b_m x_{mn} + e_n, \end{aligned}$$

where the parameters $b_0, b_1, b_2, \ldots, b_m$ and the disturbances (errors) $e_1, e_2, \ldots, e_n$ are unknown quantities.

Thus, we have a linear regression model in the matrix form:

$$Y = B \cdot X + e,$$

where

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ y_n \end{bmatrix}$$ is the vector of the response values;

$$X = \begin{bmatrix} 1 & x_{11} & x_{12} & \ldots & x_{1m} \\ 1 & x_{21} & x_{22} & \ldots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & x_{n1} & x_{n2} & \ldots & x_{nm} \end{bmatrix}$$ is the matrix of factor values;

$B = \begin{bmatrix} b_0 \\ b_1 \\ \ldots \\ b_m \end{bmatrix}$ is the vector of regression coefficients;

$e = \begin{bmatrix} e_0 \\ e_1 \\ \ldots \\ e_n \end{bmatrix}$ is the vector of deviations (errors) of the regression from the actual value.

The task is to find such a vector B for which equation (6.4) would be true and all the prerequisites of the MLR indicated in the above proposed methodology would be fulfilled.

Finding the required coefficients of B is carried out by the method of least squares. Let's present this method in the matrix form:

$$\mathrm{B} = \left(\mathrm{X}^{\mathrm{T}} \cdot \mathrm{X}\right)^{-1} \mathrm{X}^{\mathrm{T}} \cdot \mathrm{Y}.$$

The computation of the matrices X^T, $(X^T \cdot X)^{-1}$ and the desired B can be easily carried out with the sue of mathematical software, for example, Mathcad, Excel, etc.

4. Analysis of the model obtained

Regression analysis allows determining the coefficients of regression b_0, b_1, b_2, . . ., b_m. It is necessary to assess how reliable such estimates are.

The regression equation quality test

1. Verification of the general quality of the regression equation (coefficient of determination R^2).
2. Testing the statistical significance of regression coefficients on the basis of t-statistic.

The obtained mathematical pricing model based on domestic market factors is also suitable for determining the state order prices. To extend the functions of this model, we supplement it with the mathematical apparatus for price determination taking into account the pricing export component.

Export prices determination External markets pricing is a more complex process than pricing in the national market. A large number of different factors affect the price of a product being promoted to a foreign market. Here, all the pricing factors can be assigned to one of the five groups, according to their nature, level and scope:

- Macro-economic factors:
  - Inflation, including prices of goods and means of production;
  - National (economic integration, domestic/foreign policy, etc.).

- Micro-economic factors:
  - Production and distribution costs (i.e. product cost by items: raw materials, components, energy costs, etc.);
  - Profit (for example, the planned rate of return, the expected profit, etc.);
  - Taxes and fees;
  - Export-import customs duties and fees;
  - The supply of and demand for the product;
  - The competing prices (competitors' prices and prices for substitute goods);
  - Production technology;
  - The consumer properties of the product (quality, reliability, prestige, etc.)
- Specific factors:
  - Operating costs;
  - Completeness of sets;
  - Warranties and service terms;
  - Promotion expenses.
- Special factors:
  - State regulation (regulation of domestic prices for the final products and their components, funding the R&D, subsidizing the final products export, supporting the product components import, and customs tariff regulation);
  - Exchange rate (namely, the volatility of the ruble rate to a basket of foreign currencies).
- Non-economic factors:
  - Political (based on the principle of political and ideological solidarity, membership in a particular organization/alliance, etc.);
  - Regional (certain territorial location, certain interests in a territory, etc.);
  - Military (when dealing with special purposes products);
  - Ethical ("who is worth of being your buyer and who is not").

In general, the export prices determination, as shown in various scientific sources includes several consecutive stages:

1. Establishment of the initial (basic) price.
   1.1. Choosing the pricing policy.
   1.2. Market research.
   1.3. Selection of the pricing method.
   1.4. Analysis of demand for export goods.
   1.5. Determination of the production and export costs.
   1.6. Accounting for the psychological aspects of consumer perception of the price.
   1.7. Accounting for the competition level in the target segment of the world market.

2. Establishment of the final price taking into account the terms and conditions of delivery of the goods.
   2.1. Accounting for discounts.
   2.2. Accounting for the basic terms of delivery.
   2.3. Accounting for payment terms.
   2.4. Accounting for the type of distribution channel.
   2.5. Accounting for price escalation.

Method of calculating the domestic price can be used as a basis for calculating the export price.

To determine the export price, a number of additional variables is included in the basic model for the domestic market price calculating; these additional variables are pricing factors when the organization is entering a foreign market:

- The demand for export goods D_{exp};
- Production costs and export customs, duties and taxes abroad (C_{exp});
- The competition level in the target segment of the world market (C_w);
- The delivery basis (IT);;
- The level of global inflation (h_w);
- The delivery terms (T_{exp});
- The exchange rate risk (R_e);
- The payment terms (PT_{exp});
- Discounts and surcharges ($Disc_{exp}$);
- The factor's commission (MC).

Next, divide all the factors into permanent and random ones. As we already know, a parameters can be considered a permanent one, only if it can be accounted and included in the built model.

Thus, among the pricing factors of the domestic and foreign markets, the following groups of permanent and random factors are distinguished:

Permanent factors:

- The demand for the product;
- The demand for the products of competing firms;
- The level of domestic inflation;
- The level of reference prices;
- The level of prices for similar goods;
- The level of global inflation;
- The exchange rate.

Random factors:

- The competition level in the target segment of the world market;
- The delivery basis;
- The delivery terms;
- The payment terms;
- Discounts and surcharges;
- The factor's commission.

Thus, a number of additional variables related to exports is included in the basic pricing model when the organization is entering the world market.

Given the proposed symbols of export price parameters in the mathematical model, it is necessary to provide an additional function of the export component in the product price:

$$f = f\left(D_{\exp}, C_{\exp}, C_w, IT, h_w, T_{\exp}, R_e, PT_{\exp}, Disc_{\exp}, \mathrm{MC}\right).$$

Then the mathematical model (6.2) takes the form:

$$\begin{array}{l}
C = C(x_1, \ldots, x_k); \\
x_1 = x_1\left(q_1, \ldots, q_{nq}\right) \quad \mathit{for} \quad \eta(x_1) \geq \eta^*; \\
x_2 = x_2(w_1, \ldots, w_{nw}) \quad \mathit{for} \quad \eta(x_2) \geq \eta^*; \\
x_3 = x_3(r_1, \ldots, r_{nr}) \quad \mathit{for} \quad \eta(x_3) \geq \eta^*; \\
x_6 = x_6\left(g_1, \ldots, g_{ng}\right) \quad \mathit{for} \quad \eta(x_6) \geq \eta^*; \\
x_{10} = x_{10}(v_1, \ldots, v_{nv}) \quad \mathit{for} \quad \eta(x_{10}) \geq \eta^*; \\
S = S\left(B_1, \ldots, B_{14}, Rp_j, K_l, e\right); \\
h = h(z_1, z_2, \ldots, z_m); \\
P_S = Ps(p_1, p_2, \ldots, p_n); \\
f = f\left(D_{\exp},\ C_{\exp},\ C_w,\ IT,\ h_w,\ T_{\exp},\ R_e,\ PT_{\exp},\ Disc_{\exp},\ \mathrm{MC}\right); \\
P = P(C, x_8, Vr, n, Np, S, h, Ps,\ f).
\end{array}$$

As can be seen, the mathematical model for determining the price of products takes in a variety of different factors that are closely related to the innovative processes development in the economy and, in particular, using innovative solutions and competencies in competitors' production.

When determining the certain contract price, various types of a price can be used depending on the features of the purchase and sale contract. They distinguish basis prices, invoice prices, world prices, monopoly prices, reference prices, exchange prices, auction prices, bidding prices, etc. An important element used in the market prices system is the discount. Discount is a method of reducing the price taking into account the market state and the terms and conditions of the contract. The following types of discounts are most widely spread: general (simple) discount, discount for exclusive importer, settlement discount, bonus discount for long-standing partners, dealer discount, quantity rebate and progressive discount, closed discounts, discounts for off-season goods, special discounts for trial consignment and trial orders.

To maintain sustainable development of the organization and to improve its competitive advantage, it is necessary to develop activities for the application of innovative technologies and competencies that ensure the production of works and services most fully satisfying to the social needs, and also ensure the products competitiveness, creating new products, as well as activities for the modernization and technical re-equipment of production in accordance with modern requirements.

In addition to determining the product prices optimal level for the organization competitiveness improvement, it is necessary to carry out a number of activities for innovation and competencies development. Such activities include the creation, production and use of new instruments and tools (machinery and equipment, buildings, structures, transfer devices), subjects of labor (materials, fuel, energy) and consumption (products to meet people's needs), technological processes, including those containing inventions and innovation proposal, methods of organizing production, labor and management; or the reconstruction and modernization of those existent ones as well as the application of core competencies in implementing all the above mentioned processes.

The consolidated list of activities for the innovations and competencies improvement can consist of the following sections:

1. The innovations and competencies economic efficiency assessment with the help of the basic generalizing index and individual indices. The basic generalizing index of such activities economic efficiency is the economic effect. Depending on the range of tasks, the economic effect can be: national-economic (the innovative activities economic effect) taking into account the interests of the national economy as a whole, or commercial taking into account the interests of a separate organization involved in the implementation of scientific-and-technological progress activity: the developer, the manufacturer or the consumer;
2. Calculations of the economic efficiency of activities for the innovations and competencies development are made at different stages of development and use of the innovations whose basis is the organization's core competencies. The national economic effect is calculated at the stages of the formation of the R&D plans and the economic-and-social development plans for preparing feasibility studies, the choice of optimum alternative, justification for the limit price and the credit decision-making. The commercial economic effect characterizing the profit (increment in profit) remaining at the disposal of the organization is calculated at the stage of use, when the price, the production capability, the operational conditions and life of new machinery are known; as well as at the stage of development by the organizations of their own scientific and technical activities for reflecting their results in the planned and cost-accounting indicators and establishing the royalties for the use of the inventions and innovative proposals. If necessary, the commercial economic effect can be determined also at the stages of the formation of plans for R&D, plans for economic and social development and plans for technical re-equipment;
3. At the stages of the formation of plans for R&D and plans for economic and social development when determining the innovations and competencies development economic effect, the following approaches should be respected:

   - Taking into account economic, social, ecological, scientific and technical, and other useful results of implementing the activities to develop innovations and competencies (as well as negative consequences if any);
   - Calculation of economic efficiency throughout the life cycle of the development and use of core competencies based innovations for the given period for each activity, including R&D, mastering the production, the production itself and using the activities results in the national economy;

- Use of economic standards and other established restrictions in the calculations; accounting for the disbalance between the incurred costs and the results received, at different times;
- Use of the normative coefficient of investment efficiency in the calculations;
- Use of estimated cost, tariffs, standards, prices (current or prospective), reflecting the quality and effectiveness of products for the consumer;

4. At the stage of use, with the purpose to stimulate design and implementation of new technics using the available core competencies, with establishing the royalty for the use of inventions, licenses, etc., accounts reflecting the results of innovation and the use of competencies accounted in the planned and accounting figures, an approach providing a flexible wholesale and retail pricing policy, as well as the investment of temporarily-free cash should be respected. Along with the basic generalizing index of the economic efficiency of activities for the innovations and competencies development, individual efficiency indices are used. They reflect the impact of national economic effect on the norms and regulations of a commercial organization and its cost performance associated with innovative activities.

   The individual indices include:

   - Cost reduction;
   - Saving materials and the fuel-energy resources;
   - Reduction of labor intensity;
   - Employee displacement, including those at work in harmful exposure
   - Saving capital investment;
   - The growth of labor productivity, etc.

     Individual indices cannot be used as the only criteria when choosing the optimum alternative;

5. The economic effect at all stages of the calculations is defined as the difference between the cost estimate of the result of the realization of the scientific-and-technological activity and the cost estimate of all resources during the entire term of its realization;
6. Under the result of the activities implementation of the innovations and competencies development are understood the identifiable useful effects of the activities implementation:

   - Production of innovative products and services that meet the needs of the population and provide the products technical level and quality improvement, saving labor, material, fuel and energy and other resources;
   - Prevention of negative impact on the environment, improvement of working conditions, etc.;

7. When determining the economic effect, all types of costs associated with the implementation of activities to develop innovations and competencies in the areas of development, production and use for the calculation period are taken into account:

- The costs for designing activities for the innovation and competencies development;
- The capital costs of the production and use of new products;
- The operating costs in the production and use of new products.

  The amount of these costs for implementing the activities to develop innovation and competencies and the entire life cycle of the innovations created forms the total costs. When determining the economic effect, the costs incurred in the given organization are taken into account;

8. The implementation period of activities for the innovations and competencies development is determined by the life cycle of the innovations being created, including the design, mastering, mass production and effective use. To calculate the economic effect as an indicator characterizing the implementation period of an activity, the calculation period is adopted that limits the term of use by the term of moral aging or renovation;
9. As the initial year of the calculation period (t_s), the year of the start of financing the works for an innovation activity implementation, including the research, is adopted. The final year of the accounting period (t_e) is defined as the year of the activity life cycle completion, based on the planned (normative) term of product renovation; in the absence of such a term the effective service life period of instruments of labor taking into account their moral aging is used instead. The calculation period (T) is determined based on the following expression:

$$T = t_s - t_e + 1.$$

From the above consolidated list of activities for improving the products quality and the production technical level, and lowering the manufacturing costs, it follows that: only the integrated approach to improving the entire life cycle of products from the development stage to the stage of shipment, taking into account the introduction of innovative technologies in production, allows achieving cost optimization and quality improvement, and manufacturing competitive products.

6.2 Approaches to the Formation of a Methodology for Justifying the Initial Contract Price for High-Tech Products

In conditions where the ceiling prices for high-tech products and services is fixed to some extent, the formation of a cost management strategy and pricing methods enhancement becomes an urgent issue to improve the enterprises economic efficiency.

The main disadvantages of the existing methodology for justifying the contract initial prices are:

- Obsolescence of extrapolation dependencies;
- Insufficient accounting for the capabilities of high-tech enterprises to perform assigned R&D projects;
- The lack of consideration of the customer's possible financial losses when forming the initial contract price;
- The discrepancy between the mechanism of bringing the initial values to a comparable type and the modern requirements.

These shortcomings lead to the fact that the customer in the initial contract price formation process often bears financial losses caused by the price overstating or understating. The error in the initial contract price formation is growing when estimating the costs for high-tech products creation that requires the use of advanced technologies.

The proposed tools for justifying the initial contract price should include:

- Determining the R&D activity content based on data on technical solutions used in similar developments;
- Forming the potential performers contract price proposals;
- Determining the initial contract price taking into account the customer's possible financial losses.

The essence of the proposed approach is as follows:

- Initial data and production process scenarios are generated, including information on the initial contract price range;
- The R&D activity content is determined;
- Potential performers' contract price proposals are formed, and the customers possible financial losses and their probability are estimated when establishing a certain value of the initial contract price;
- The initial contract price corresponding to the minimum probable customers financial losses is determined.

A block diagram for justifying the initial contract price is presented in Fig. 6.2.

The initial data are the data of the Request for Proposals (RFP) for R&D and information on earlier performed R&D projects, as well as the initial contract price range, where the upper limit price is set by the Customer, based on the budget capabilities; the lower initial price should be determined if the level of profitability is not set, in which case it is equal to the cost of work; if this level is set, it is equal to the cost of work taking into account the level of profitability; in this case the lower initial price is the contract initial price. At the same time, certain norms of the performers overhead costs and the risk component should be taken into account in the range of the initial price, as well as the inflationary expectations (for projects longer than 1 year); a separate item in the budget should provide for the a prototype model creation expenses (Fig. 6.3).

The task of determining the activity content is solved separately for Research and for Development. To assess the research activity content, finding similar research tasks is performed and the degree of their proximity using the methods of semantic

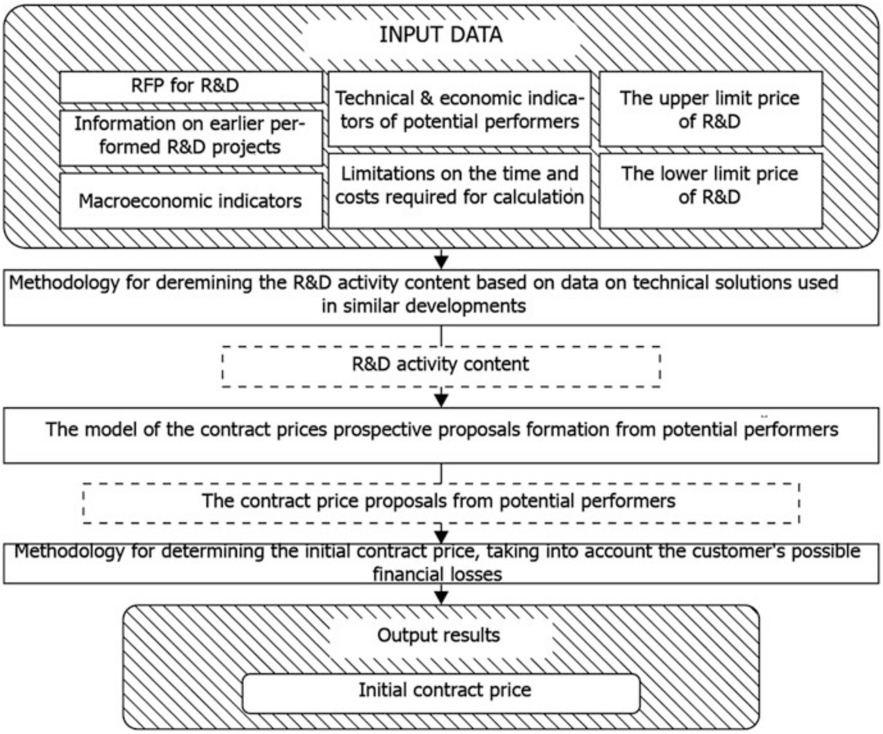


Fig. 6.2 Block diagram for justifying the initial contract price

and ranging analysis of data is then assessed. Further, the relative complexity factors of the assigned and similar research tasks are determined and the activity content of the tasks and the work as a whole is calculated using the various methods selected depending on the specifics of a particular product.

The approach to determine the R&D activity content based on data on technical solutions used in similar developments is designed to assess the labor content of all employee groups of the enterprise. The essence of the proposed approach is decomposing a rocket and space technology sample created within the framework of development work, into components and determining the activity content of their creation and the Development activity content as a whole. The activity content of samples component parts creating is determined on the basis of the adjusted activity content of creating similar components using proximity coefficients, factors of relative complexity and activity content reduction. Methods of data ranging and their semantic analysis are used for finding similar component parts and assessing the degree of their proximity. The output results of this stage are used as input data for the stage of potential performers' contract price prospective proposals formation.

Algorithm of the potential performers' contract price prospective proposals formation simulates the behavior of potential performers invited to tender for

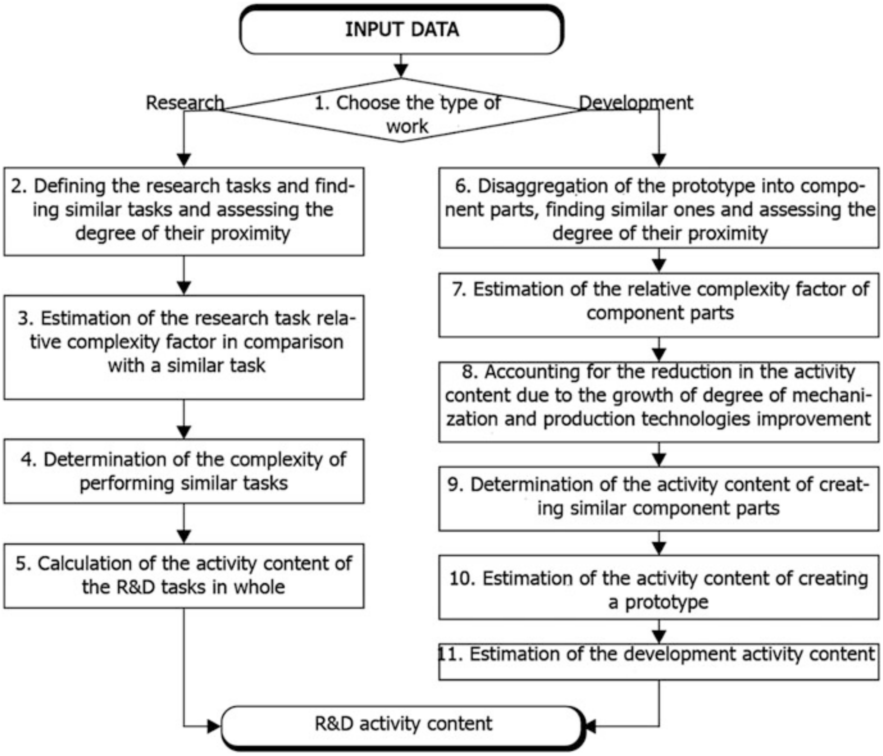


Fig. 6.3 Block diagram of the methodology algorithm for assessing the R&D activity content based on technical solutions used in similar developments

development of a rocket and space tech product in terms of assessing its value. The block diagram of the algorithm of the model is shown in Fig. 6.4.

The initial data are: the data of Requests for Proposals for R&D, technical and economic indicators of potential performers, R&D macroeconomic indicators and activity content. The input data is prepared for the calculations in the Preparatory block. First, a list of potential performers is formed based on information on the intellectual activity results obtained in the course of earlier performed R&D works. Next, the expected level of profitability and the overhead costs ratio are estimated, the insurance rates are précised and changes in prices for the main resources used in performing R&D are forecasted to account for the inflationary development. The output result of the block is the forecast values of technical and economic indicators of potential performers and the expected inflation indices.

The potential performers contract price prospective proposals are directly formed in the Estimation block based on the data obtained in the Preparatory block and the R&D activity content. First of all, the labor costs evaluation is made more precise, for which purpose the list of work collective at various stages of work is defined. The

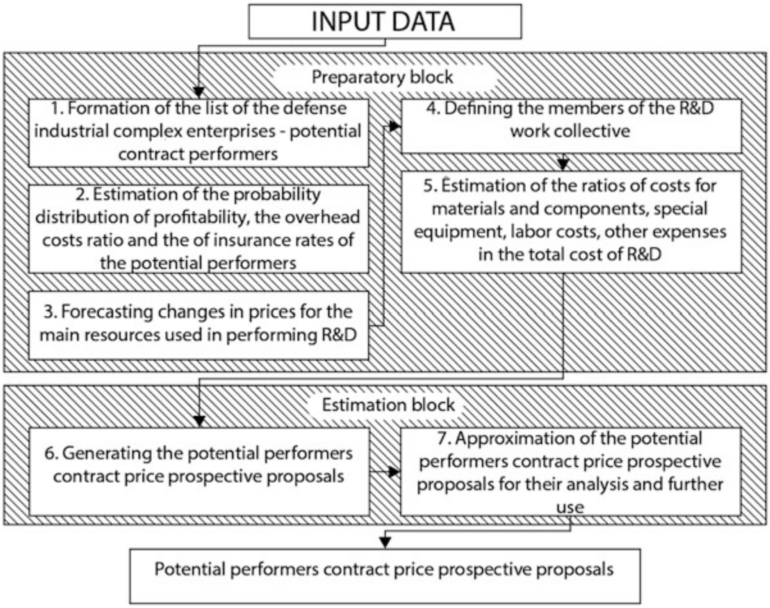


Fig. 6.4 Block diagram of the potential performers' contract price prospective proposals formation model

costs for materials and components, special equipment and other expenses are determined according to their average share in the R&D total costs. Further, the potential performers contract price proposals are generated using the Monte Carlo method. The result of implementing the algorithm of the model are sets of the potential performers contract price proposals.

The feature of the model is to take into account predictive estimates of potential performers technical and economic indicators, change in prices for the main resources used in performing R&D, as well as the use of the Monte Carlo method to account for uncertainties in determining the initial contract price. The output result of the algorithm is used in the methodology for determining the initial contract price based on the customer possible financial losses. The block diagram of the methodology algorithm is presented in Fig. 6.5.

The initial data of the methodology are the potential performers contract price proposals, the upper and the lower limit prices. The methodology determines the customer probable financial losses considered as a combination of the customer possible financial losses and the probability of their occurrence. First, the customer possible financial losses in range of permissible values of the initial contract price is assessed, which is limited to the right by the upper limit price, and is limited to the left by the lower limit price on the value axis.

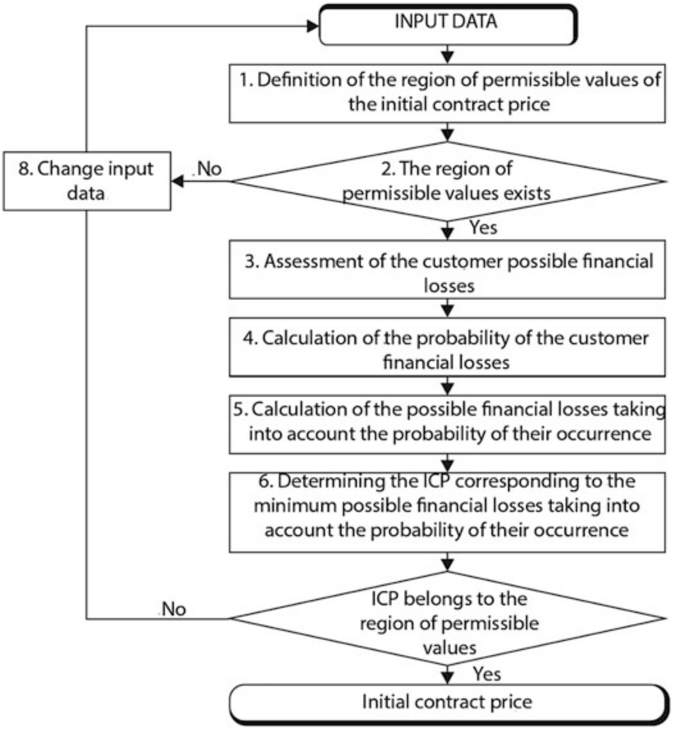


Fig. 6.5 The block diagram of the algorithm of the methodology for determining the initial contract price based on the customer possible financial losses

The customer financial losses are possible in two cases:

- Disruption of the tender due to the understated initial contract price;
- The initial contract price exceeded the upper limit price.

In case of tender disruption, the customer is forced to bear additional costs: inflationary costs; costs associated with the need to perform R&D in a shortened time frame; costs for re-tendering procedures.

Financial losses of the customer arising from inefficient use of resources are due to the excess of the initial contract price over the upper limit price. Since the financial losses due to the tender disruption, and losses due to the inefficient use of financial resources cannot be realized at the same time, in subsequent calculations the larger of them are taken.

The probability of the customer financial losses is determined by loading the probabilistic distribution of the potential performers' contract price proposals up to accumulated value of one, taking into account the range of permissible values of the initial contract price. The estimation of the customer possible financial losses is made using the multiplicative convolution of the probability of these losses and their size.

The result of the calculation using the methodology is the initial contract price corresponding to the customer minimum possible financial losses taking into account the probability of their occurrence. The novelty of the methodology consists in accounting for the possibility of inefficient use of financial resources due to overstating the initial contract price, the possibility of financial losses in case of tender disruption due to understating the initial contract price, and also to take into account the military-economic feasibility of R&D.

6.2.1 Earned Value Method in Pricing for Products

Traditionally, the time-dependent difference $D0\ (t) = c0\ (t) - c\ (t)$ between the budgeted costs (Budgeted Cost of Work Scheduled—BCWS) $c0(t)$ (the amount of money that was planned to be spent by time t) and actual costs $c(t)$ (Actual Cost of Work Performed—ACWP, i.e. the actual amount of money spent) was traditionally considered to be the main indicator of the cost dynamics. The positive value of $D0(t)$ means, firstly, that the actual costs are lagging behind the budgeted ones, which can be caused by external (from the perspective of the considered project) reasons, for example, delays in financing, etc., that is, lack of funds; and, secondly, that there is a delay in the performance of work. This ultimately can lead to a delay in the completion of the project as a whole.

However, the value of $D0(t)$ is not sufficient to make sound judgments, for example, on the possible completion dates of the project, since the actual state of the project is characterized not only by actual costs (ACWP) but also by budgeted costs (BCWP) $ce(t)$, sometimes called the Earned Value (EV) in the literature, which can, for some internal reason (from the perspective of the project under consideration), be different from actual costs. The quantity $D(t) = c0(t) - ce(t)$ will characterize the backlog from the plan, and the quantity $De(t) = c(t) - ce(t)$ is the cost overrun.

For the first time, the "three-dimensional" description of the work: "what was planned to spend—what was spent—what was done" began to be applied by engineers at the end of the nineteenth century. In the late 1950s, network models appeared (including the PERT—Program Evaluation Review Technique in 1958), based on the critical path method and allowing one to determine the optimal sequence of operations execution from the point of view of the project completion time. In 1962, the PERT/Cost method was introduced, which takes into account not only temporal but also cost-based characteristics. Therefore, the appearance of the system of the US Department of Defense, the C/SCSC (Cost-Schedule Control Systems Criteria) may be conditionally dated by 1967, for since that year the use of the Earned Value Method is compulsory for projects carried out in the framework of execution of the Ministry of Defense state order. In 1986, the number of criteria was reduced; nevertheless, they are used mainly in government contracts: the complexity of the description, the complexity of the application, etc. lead to the fact that 99% of commercial projects do not use C/SCSC. The simplified Earned

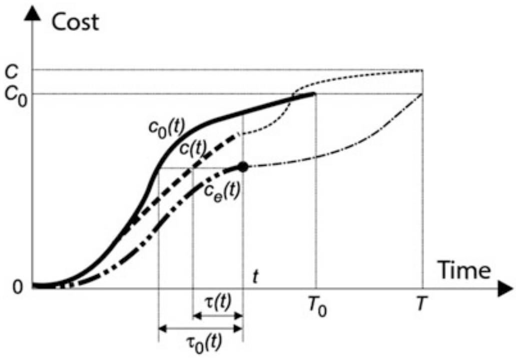


Fig. 6.6 Budgeted, actual and earned costs of the project

Value Method, described below, has become more widespread, including in commercial projects.

Consider an elementary project, that is, a project consisting of one operation. The graph of the dynamics of costs is shown in Fig. 6.6.

Here are the main variables that describe each operation and the project as a whole ("the earned value basic indicators"):

C_0	Budgeted total project costs (BAC—Budget At Completion, or BC—Budget Cost);
T_0	The expected completion date of the project;
$c_0(t)$	The planned cost dynamics (BCWS—Budgeted Cost of Work Scheduled)—the directive schedule;
c(t)	The actual dynamics of the costs (ACWP—Actual Cost of Work Performed);
$c_e(t)$	Earned cost dynamics (BCWP—Budgeted Cost of Work Performed, or EV—Earned Value);
T	The actual completion date of the project;

Derivative earned value indicators:

$D0(t) = c0(t) - c(t)$	The difference between the budgeted and actual costs;
$D(t) = c0(t) - ce(t)$	The difference between the budgeted and earned costs;
$De(t) = c(t) - ce(t)$	The difference between the actual and earned costs (Cost Overrun);
$a(t) = ce(t)/c0(t)$	Schedule Performance Index (SPI);
$b(t) = ce(t)/c(t)$	Cost Performance Index (CPI).

If the project consists of several operations, then the question arises of how to aggregate the indicators of subprojects, operations, etc. An important role here plays the Work Breakdown Structure (WBS)—the tree of works in which the project is being successively broken down into smaller components), and the Cost Control Plan (CAP)—a set of procedures for determining the values of the elements of the Work Breakdown Structure and the rules of their aggregation.

6.2.2 Methods for Measuring Earned Value

To date, the most widely used methods for measuring the earned value are as follows:

- The method of weighted milestones is the enumeration for each operation (work package, etc.) of milestones—the criterion values of performance indicators, the achievement of which means the completion of a certain stage. In doing so, the earned value is measured as a weighted value of the achieved normative indicators. This method is well adapted for measuring the result of planning and management;
- The method of a fixed formula for an individual operation consists in assigning to each operation a fixed ratio x%/y% (for example, 0/100, 25/75, 50/50, etc.), according to which the operation beginning is considered to correspond x% of value earned, and its completion corresponds y%;
- "Percent Completed" method. This method on the one hand is one of the simplest—an estimate of the percentage of completion is used for each operation, then these estimates are aggregated according to a predetermined methodology. On the other hand, the drawback of this method is, among other things, the presence of the so-called "90% syndrome"—the operators report the operation (stage, etc.) is "almost" complete, while before the actual completion, there may be still very far (both in terms of time, and in terms of the required resources). Therefore, it is recommended a priori to establish a 80–90% boundary for an uncompleted project or operation;
- Combination of methods of Milestones and Percent Complete: the milestones set criterion values, reducing the possibility of information distortion;
- Equivalent Completed Units method is the introduction of a unified system of reference (work units). The advantage of this method is that in some cases it is possible to achieve additivity of individual operations estimates. The Percent Complete method can be considered as a variation of the Equivalent Completed Units method (when the completion units);
- The Earned Standards method is to establish for each operation detailed standards (much more detailed than in the method of milestones), the achievement of which means a certain earned value. This method allows for a very "accurate" measurement of the earned value, but its use requires extensive preparatory work, as well as regular and labor-consuming project monitoring (collection and processing of a significant amount of information).

6.3 Optimal Pricing in the High-Tech Industry to Ensure Its Sustainability

Currently, many sectors of the economy require finding new ways to maintain price levels that would allow for products to remain competitive while their quality and reliability would be no worse than that of competitors.

There are several ways: reduction of labor intensity of production due to organizational and technical measures, increase of labor productivity, etc. An important issue is the maintenance of the rate of return if it is a question of the main products of enterprises and the profitability improvement in order to form the innovative development fund when it comes to non-core products.

These issues require an unconventional approach to their solution. One of such problems is the problem of the transfer pricing efficient management in vertically integrated companies, the solution of which will allow enterprises for successful development.

Since there is competition among high-tech enterprises producing the same type of products, even the state in the conditions of market relations is interested in buying products at a reasonable price, not to mention the tough competition in foreign arms markets. So recently, Indian authorities refused to purchase 126 French Rafale fighters in favor of Russian military aircraft, and, as the Indian newspaper The Times of India notes, the Russian contract will be much larger than the French one.

Taking into account the fact that the products manufactured under the state order go to the Armed Forces of the Russian Federation and some of the military products go to foreign arms markets, it is possible to prove mathematically that in vertically integrated corporations, the maximum profit from the sale of finished goods is possible only at the parent enterprise, if the level of profitability of gross income (value added) to wholesale costs for component parts is equal to the optimal value, which corresponds to the optimal price of sale of finished products in the arms markets and effective transfer pricing. It is also easy to calculate the optimal volume of manufactured high-tech products at the optimum sale price.

Traditionally, when determining the optimum sale price and the volume of production, we proceed from the following assumptions:

1. The immutability of the sales price and the prices for inputs and components consumed.
2. The division of enterprise costs into fixed ones, which remain unchanged with significant changes in volume, and variable ones that vary in proportion to the volume.
3. Proportionality of incoming revenues to sales volume.
4. The existence of a single breakeven point (which follows from the above conditions).
5. Constancy of product range.
6. Equality of production volume to sales volume.

It is clear that the described system of prerequisites is very rigid and does not take into account the change in potential consumers' demand on enterprises products.

Therefore, when solving the problem of determining the optimum selling price and volume of production, we will take into account:

- Mismatch between production volume and sales volume,
- Change in the wholesale prices of components for manufacturing products by the parent enterprise.

Consider the method of calculating the optimum gross income when selling products by the parent enterprise taking into account the market demand elasticity.

Let $A = \{a_j \mid j = 1, 2, \ldots, n_u\}$ be a set of types of products manufactured by the parent company of the corporation. As the main indicator, we will consider the proceeds (earnings) of the parent enterprise $E(Q, P)$ which is equal to the product of $Q_j a_j$-x product units sold at the selling price P_j^S

$$E = \sum_{j=1}^{n_и} E_j = \sum_{j=1}^{n_и} Q_j \cdot P_j^S, \tag{6.5}$$

where $n_и$ is the number of types of a_j-x products, manufactured by the parent enterprise.

The Cost of Components for manufacturing the j-th item is presented in a generalized form

$$CC_j = \sum_{l=1}^{n_j} x_l w_l \tag{6.6}$$

where x_l the amount of components of the l-th plant of the supplier for the manufacture of the j-th item;

w_l is the price of components of the l-th plant of the supplier;

n_j—the amount of components for the j-th item.

Then the proceeds B_j from the sale of the j-th item can be presented in the form of a sum of costs for components CC_j and the gross value added GVA_j:

$$E_j = CC_j + GVA_j, \tag{6.7}$$

The gross value added GVA_j consists of the planned income I_j and value added tax VAT_j attributable to the j-th item of the parent enterprise:

$$GVA_j = I_j + VAT_j, \tag{6.8}$$

Taking into account the value added tax rate μ_{VAT}, the gross added valueGVA_j (6.8) for the $T_k = [t_k, t_{k+1}]$ period of time in the amount of the proceeds $B_j(T_k)$ of the j-th item will be:

$$GVA_j(T_k) = I_j(T_k) \times \left(1 + \frac{\mu_{VAT}}{100\%}\right), \tag{6.9}$$

where $VAT_j(T_k) = \frac{\mu_{VAT}}{100\%} \times I_j(T_k),$ is the amount of value added tax, μ_{VAT} is the rate of value added tax in %.

Hence the income is calculated by the formula:

$$I_j(T_k) = GVA_j(T_k) \times \left(1 + \frac{\mu_{VAT}}{100\%}\right)^{-1}, \tag{6.10}$$

Introduce the indicator of the rate of gross added value GVA_j to the sum of the costs of components CC_j in manufacturing the j-th item in the form:

$$rGVA_j = \frac{GVA_j}{CC_j} \times 100\%, \tag{6.11}$$

from which the profitability of income I_j to the cost of components CC_j can be represented as:

$$rI_j = \frac{I_j}{CC_j} \times 100\%. \tag{6.12}$$

Income, in turn, includes distribution costs (DC) associated with the sale of enterprise products, a payroll budget (PB) and balance profit (profit before tax) (BP):

$$I_j = BP_j + PB_j + DC_j, \tag{6.13}$$

where $NP_j = BP_j \times \left(1 - \frac{\mu_{BP}}{100\%}\right)$, is the net profit, μ_{BP} is the balance profit tax in %; $RL_j = PB_j \times \left(1 + \frac{\mu_{RL}}{100\%}\right)^{-1}$, is the remuneration of labor, μ_{RL} is the social tax on wages in %.

The question arises: at what price of sales the income will be maximized, and accordingly, the revenues to the state budget will be maximal? In this regard, we study the amount of total revenue (sales volume) and revenues depending on the intensity of finished products sales by the parent enterprise, which depend on the suppliers' planned profitability of gross income, components for the parent enterprise, on which the selling price of finished products will depend (the issue price), ensuring the receipt of maximum net income.

Let's introduce the following notation:

$P_j^{Cc}(t_k)$ is the price of the costs of components in the selling price P_j^S of the j-th item at the t_k point in time;

$P_j^I(t_k)$ is the part of the selling price of the j-th item, which goes to the formation of the amount of income (profits before taxes);

$P_j^{VAT}(t_k)$ is the part of the price to be paid as the value added tax;

$Q_j(t_k)$ is the physical volume of sales of j-th item in $t_k \in T = [t_1, t_2, \ldots, t_k, \ldots)$ time (month, quarter, half-year, year).

Formally, the price of the cost of components $P_j^{Cc}(t_k)$ in the selling price P_j^S of the j-th item at the moment of time t_k with account of $CC_j(t_k)$ (6.6) is determined from equality

$$Q_j \times P_j^{Cc} = \sum_{l=1}^{n_j} x_l w_l \Rightarrow P_j^{Cc} = \frac{\sum_{l=1}^{n_j} x_l w_l}{Q_j}. \tag{6.14}$$

Hence the selling price of the j-th item at the moment of time t_k can be represented as:

$$P_j^S(t) = P_j^{Cc}(t) + P_j^I(t) + P_j^{VAT}(t), \tag{6.15}$$

and the gross value added price $P_j^{GVA}(t_k)$ in the selling price $P_j^S(t_k)$ of the j-th item at time $t_k \in T$ will be:

$$P_j^{GVA}(t_k) = P_j^I(t_k) + P_j^{VAT}(t_k). \tag{6.16}$$

The level of gross value added in the price of the j-th item at the time t_k:

$$rGVA_j(t_k) = \frac{P_j^{GVA}(t_k)}{P_j^{Cc}(t_k)} \times 100\% \tag{6.17}$$

Determine the intensity of sales of the j-th product over a period of time $T_k = [t_k, t_{k+1}]$:

$$q_j(t_k) \approx \frac{Q_j(t_{k+1}) - Q_j(t_k)}{t_{k+1} - t_k} = \frac{\Delta Q_j(t_k)}{\Delta t_k}, \quad \Delta t_k = t_{k+1} - t_k, \tag{6.18}$$

from where $Q_j(T_k) = q_j(t_k) \cdot \Delta t_k$.

Usually the price of the product is composed of the ratio of supply and demand. In view of this, the problem arises: to find *the optimal gross value added rate* in the selling price $P_j^S(t_k)$ (6.15) of the j-th item under the current market conditions. In conditions of elastic demand, with a decrease in the rate $rGVA_j$ (6.11), the intensity of the final product sale $q_j(t_k)$ (6.18) within a given period of time t_k (quarter, year) increases. We assume known: the maximum size of the rate $rGVA_j$ (6.11) ensuring profitability of income I_j (6.10) of the j-th item in the interval $T_k = [t_k, t_{k+1}]$:

$$rGVA_j^* = \max_{t \in T_k} rGVA_j(T_k) \tag{6.19}$$

and the minimum size of the rate of return on gross income $rGVA_{j*}$:

$$rGVA_{j*} = \min_{t \in T_k} rGVA_j(T_k) \tag{6.20}$$

It is clear that the maximum rate of gross value added $rGVA_j^*$ (6.18) will correspond to the minimum sales intensity which we will denote as $q_{\#j}$:

$$q_{j\#} = \min_{t \in T_k} q\left(rGVA_j^*(T_k)\right), \tag{6.21}$$

and the minimum rate $rGVA_{j*}$ (6.20) will correspond to the maximum intensity of the sale which we will denote as $q_j^{\#}$:

$$q_j^{\#} = \max_{t \in T_k} q\left(rGVA_{j*}(T_k)\right). \tag{6.22}$$

To obtain applied calculation formulas, we will assume that the intensity of sales in the interval $T_k = [t_k, t_{k+1}]$ is approximated by a linear decreasing function (see Fig. 6.7):

$$q_j\left(rGVA_j\right) = \beta_j - \alpha_j rGVA_j. \tag{6.23}$$

where $\alpha_j = \dfrac{\Delta q_j}{\Delta rGVA_j} = \dfrac{q_j^{\#} - q_{j\#}}{rGVA_j^* - rGVA_{j*}}$, $\beta = \dfrac{q_i^{\#} rGVA_j^* - q_{i\#} rGVA_{j*}}{rGVA_j^* - rGVA_{j*}}$.

Taking into account $P_j^S(t_k)$ (6.15) the proceeds $E_j(T_k)$ for Q_j items over time T_k is the amount of

$$E_j(T_k) = Q_j(T_k) \times P_j^{Cc} + Q_j(T_k) \times P_j^I \times \left(1 + \frac{\mu_{VAT}}{100\%}\right), \tag{6.24}$$

and the amount of income taking into account $GVA_j(T_k)$ (6.9) can be represented in the form:

$$I_j\left(rGVA_j\right) = Q_j(T_k) \cdot P_j^{GVA} \cdot \left(1 + \frac{\mu_{VAT}}{100\%}\right)^{-1} = \frac{rGVA_j}{\mu_{VAT} + 100\%} \cdot q_j\left(rGVA_j\right) \cdot \Delta t_k \cdot P_j^{Cc}. \tag{6.25}$$

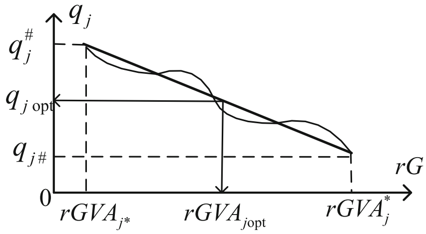


Fig. 6.7 Dependence of sales intensity on the level of gross value added

Then the formulation of the optimization problem is reduced to finding the optimal gross value added rate $rGVA_{j\,\mathrm{opt}}$ that provides the maximum income $I_j(rGVA_j)$ (6.24), i.e.:

$$I_j\left(rGVA_{j\,\mathrm{opt}}\right) = \max_{rGVA_j \in \left[rGVA_{j*}, rGVA_j^*\right]} I_j\left(rGVA_j\right), \tag{6.26}$$

provided that the demand for the products of the corporation in the arms markets is elastic for $q_j(rGVA_j)$ (6.22).

As the basis for calculating the maximum income and the value added tax coming to the state budget, taking into account the elasticity of demand on the corporation production, we put the following theorem:

Theorem 1 *In order for the income function $I_j(rGVA_j)$ (6.25) at constant price of the components to reach the maximum value in conditions of elastic demand on the j-th item $q_j(rGVA_j)$ (6.23) over a period of time T_k, it is necessary and sufficient to set the gross value added rate at sale equal to:*

$$rGVA_{j\,\mathrm{opt}} = \frac{\beta_j}{2\alpha_j} = \frac{q_j^{\#} rGVA_j^* - q_{j\#} rGVA_{j*}}{2\left(q_j^{\#} - q_{j\#}\right)}. \tag{6.27}$$

Proof. Substitute the intensity function of $q_j(rGVA_j)$ (6.23) in $I_j(rGVA_j)$ (21) and find the optimal solution of the maximization problem (6.26). A necessary condition for the existence of a maximum is the equality of the first derivative of the function of $I_j(rGVA_j)$ (6.25) to zero:

$$\frac{dI_j(\Delta t_k)}{drGVA_j} = \left(\beta_j - 2\alpha_j rGVA_j\right) \frac{\Delta t_k \cdot P_j^{Cc}}{\mu_{VAT} + 100\%} = 0, \tag{6.28}$$

from which follows the expression $rGVA_{j\,\mathrm{opt}}$ (6.27). The necessity is proved.

The sufficiency follows from the fulfillment of condition

$$\frac{dI_j^2\left(rGVA_j\right)}{d\left(rGVA_j\right)_2} = -2\alpha_i \cdot \frac{\Delta t_k \cdot P_j^{Cc}}{\mu_{VAT} + 1} < 0. \tag{6.29}$$

The theorem is proved.

Since $q_{j\mathrm{opt}}\left(rGVA_{j\mathrm{opt}}\right) = \dfrac{q_i^{\#} rGVA_j^* - q_{i\#} rGVA_{j*}}{2\Delta rGVA_j}$, the maximum income attributable to the j-th item of the parent enterprise at the optimal $rGVA_{j\,\mathrm{opt}}$ is:

$$I_j^*\left(rGVA_{j\,\mathrm{opt}}\right) = \frac{rGVA_{j\ \mathrm{opt}}}{\mu_{VAT} + 100\%} q_{j\ \mathrm{opt}} \Delta t_k P_j^{Cc} = \frac{\left(q_j^{\#} GVA_j^* - q_{j\#} rGVA_{j*}\right)^2 P_j^{Cc} \Delta t_k}{4\Delta q_j \cdot \Delta rGVA_j \cdot (100\% + \mu_{VAT})}, \tag{6.30}$$

and in general for all items

$$I_{\Sigma} = \sum_{j=1}^{n_{и}} I_j^* \left(rGVA_{j\ \mathrm{opt}}\right). \tag{6.31}$$

where n_u is the number of items manufactured by the parent enterprise.

Hence the maximum gross added value for the j-th item is:

$$GVA_j^* = I_j^* + VAT_j^*, \tag{6.32}$$

where $VAT_j^* = \mu_{VAT} I_j^*$.

The maximum VAT coming in the state budget:

$$VAT_{\Sigma} = \sum_{j=1}^{n_{и}} VAT_j^* (\delta t) = \mu_{VAT} \cdot \sum_{j=1}^{n_{и}} I_j^* \left(rGVA_{j\ \mathrm{opt}}\right) = \mu_{VAT} I_{\Sigma}, \tag{6.33}$$

In the conditions of market relations, the manufacturer sets the price for products based on the rate of return on gross income. However, due to the economic law of supply and demand, the seller is forced to set a real (optimal) rate at which the product would be sold.

Let us consider an example of calculating the optimal ratio of gross value added to the cost of components and the selling price of the parent enterprise products when selling three types of products to obtain a net maximum income. Notional data for two time periods are given in Table 6.1.

In order to calculate the optimal values of the level of gross value added, at which the maximum income is ensured, it is necessary to have information about the various values of the sales intensity and the corresponding profitability rates. In the simplest case, it is enough to know about two different values of sales intensity and corresponding profitability rates, one of which is taken for maximum intensity, and the other one is taken for minimum intensity.

Based on the sales statistics in (Table 6.2), the results of calculating the ultimate values of sales intensity and the corresponding rates of gross value added, as well as the calculated income, are presented.

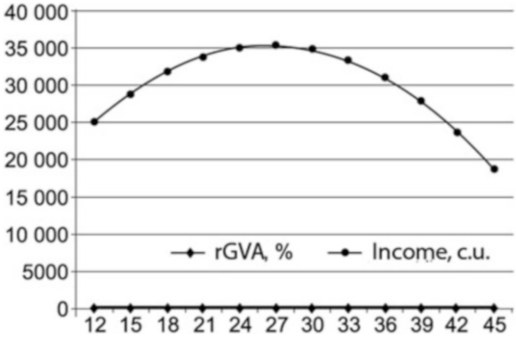
Table 6.1 Sales statistics

Item number	P_j^{Cc}—cost of components (c.u.)	The period of sales statistics collection							
		Period 1				Period 1			
		P_j^S c.u.	Q_j pcs	Δt_1 month	$q_j(\Delta t_1)$ pcs/month	P_j^S c.u.	Q_j pcs	Δt_2 month	$q_j(\Delta t_2)$ pcs/month
Item no. 1	2700	3024	90	6	15	3915	18	6	3
Item no. 2	3500	3780	160	8	20	4900	40	8	5
Item no. 3	4800	5664	60	5	12	7296	20	5	4

Table 6.2 Estimates at the18% VAT rate

Item number	$q_j^{\#}$	$q_{j\#}$	$q_{j\,\mathrm{opt}}$	$rGVA_{j*}$ %	$rGVA_j^*$ %	$rGVA_{j\,\mathrm{opt}}$, %	$I_j(rGVA_{j*})$	$I_j(rGVA_j^*)$	$I_j(rGVA_{j\,\mathrm{opt}})$
Item no. 1	15	3	9.7	12	45	27	24,712	18,534	35,390
Item no. 2	20	5	11.9	8	40	25	37,966	47,458	71,384
Item no. 3	12	4	8.1	18	52	35	43,932	42,305	56,961

Fig. 6.8 Graph of income *I* dependence on the gross value added rate *rGVA*, %



In Fig. 6.8 shows the graph of income dependence on the gross value added rate in the selling price of item No. 1.

Thus, the parent enterprise can receive the maximum income at the optimal level of gross value added in the selling price of manufactured products.

Obviously, if the companies supplying components for manufacturing the final products, presented in the form of a set $L = \{\pi_l\}_{l=1}^{n_L}$, are parts of a vertically integrated structure, then with transfer pricing it is reasonable to plan the parent enterprise maximum income and corresponding finished products sale profitability. Only after the sale of finished products, suppliers should receive their share $\gamma_l \in (0, 1)$ of income I_l of the income I_Σ received by the parent enterprise from the sale of products of the *j*-th type, based on the ratio:

$$I_l = \sum_{l=1}^{n_j} \gamma_l \cdot I_\Sigma, \sum_{l=1}^{n_j} \gamma_l = 1. \tag{6.34}$$

The obviousness of this proposition follows from the reasoning below: The optimum selling price $P_{j\,\text{opt}}^{S}(t_k)$ with constant price of components $P_j^{Cc} = \text{const}$ will also correspond to the optimal rate of profitability $rGVA_{j\ \text{opt}}$ (6.26):

$$P_{j\text{opt}}^{S} = P_j^{Cc} + P_{j\text{opt}}^{GVA}(t) = P_j^{Cc} \times \left(1 + \frac{rGVA_{j\text{opt}}}{100\%}\right). \tag{6.35}$$

In turn, the maximum proceeds for the sale of *j*-th items will correspond to the maximum income $I_j^*\left(rGVA_{j\ \text{opt}}\right)$ (6.28):

$$E_j^* = Q_{j\text{opt}} \cdot P_{j\text{opt}}^{S} = CC_j + GVA_j^* = Q_{j\text{opt}} P_j^{Cc} + I_j^* \times \left(1 + \frac{\mu_{VAT}}{100\%}\right), \tag{6.36}$$

Where $CC_j = Q_{j\text{opt}} P_j^{Cc}$ is the cost of components for *j*-th item;

$$GVA_j^* = I_j^* \times \left(1 + \frac{\mu_{VAT}}{100\%}\right).$$

Hence the maximum income:

$$I_j^* = \left(E_j^* - Q_{jopt} P_j^{Cc}\right) \times \left(1 + \frac{\mu_{VAT}}{100\%}\right)^{-1}. \tag{6.37}$$

Obviously, the optimal sales volume Q_{jopt} corresponds to the optimum selling price P_{jopt}^S (6.35). Fix values E_j^* (6.36) and GVA_j^* (6.31). Let the prices for components increase by δP_j^{Cc} and, using formula (6.37), we determine the income of the parent enterprise

$$I_j^*\left(\delta P_j^{Cc}\right) = \left[E_j^* - Q_{jopt} \times \left(P_j^{Cc} + \delta P_j^{Cc}\right)\right] \times \left(1 + \frac{\mu_{VAT}}{100\%}\right)^{-1}. \tag{6.38}$$

In this case, the income of the parent enterprise $I_j^*\left(\delta P_j^{Cc}\right)$ due to the increase in the price of components by δP_j^{Cc} will be reduced by

$$\delta I_j^* = I_j^* - I_j^*\left(\delta P_j^{Cc}\right) = Q_{jopt} \times \delta P_j^{Cc} \times \left(1 + \frac{\mu_{VAT}}{100\%}\right)^{-1}. \tag{6.39}$$

To compensate for the decline in the income, the parent enterprise will have to raise the selling prices. This, taking into account the dependence of the sales intensity on the level of gross value added (6.23), will lead to a drop in demand in the arms markets. In this case, the need for components will decrease, which will lead to a drop in revenues and profitability of the supplier enterprises that are part of the integrated structure of the corporation.

A more sophisticated problem arises when a supplier enterprise is not a part of the integrated corporation legally, but is involved in the supply of components for the manufacture of products by the parent enterprise of the corporation.

Consider a non-linear model of taxation in the parent enterprise sales on the criterion of maximizing income in conditions of elastic demand based on two options: the fixed and non-linear VAT rate.

Taxes account for a predominant share of the revenue side of the budget. The tax system of Russia which has been in force since 1992 is characterized by the predominance of the fiscal function, with complete disregard for the functions of regulating and stimulating the real economy. The EU taxation system with its relatively high role of indirect taxes, especially VAT, was chosen as the main model for imitation. However, studies show that the EU taxation system has being built for a long time and now it helps to curb the crisis of overproduction. Proceeding from this, the tax system of Russia should on the contrary stimulate economic processes and promote the real economy development. What should be the tax mechanism, including the rates of taxes, duties, tariffs, excises to stimulate the real economy, on the one hand, and to ensure sustainable economic development without spiraling the inflation on the way to the developed economy, on the other hand?

It is clear that the tax burden should be reduced. However, it is also clear that tax revenues to the budget will decrease in the beginning.

It is usually proposed to solve the problem of sustainable economy performance with the help of the following measures: reduction of government spending, introduction of a progressive taxation scale, restraining the growth of wages, changing the amount of money in circulation. However, the Russian experience shows that such a "monetarist" policy is unable to solve the crisis of non-payments, to provide industrial growth and improve the well-being of citizens. An artificial hold on money supply in the economy in accordance with the monetarist recipes could not abolish the exchange function of money; any goods which could be used in barter trade became a money substitute. Anyway, it is necessary to recognize that in the conditions of instable ruble, the national currency, payment for the national budget deficiency by money emission and debt repayment to state-financed organizations can lead to growing unsatisfied demand on consumer goods on the part of the bulk of the population and, as a consequence, to unwinding of the flywheel inflation.

To solve this problem, consider a nonlinear model of an effective tax mechanism that ensures the economic development sustainability and suppression of the inflation. The idea is to introduce a progressive non-linear scale not only in relation of the corporate income, but in relation of the trade mark-ups of both wholesale and retail levels. Mathematically, this can be represented as a monotonically increasing function of dependence of the VAT rate or the rate of turnover tax on the level (rate) of gross income:

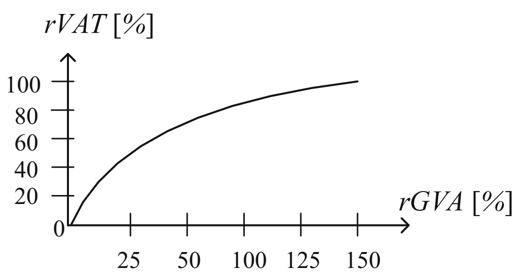
$$rVAT = f(rGVA) \tag{6.40}$$

Graphically, this dependence is shown in Fig. 6.9. This mechanism does not allow the seller, even monopolistically dominant in any market, to inflate the price of the product with increasing demand from the population.

The introduction of this non-linear taxation will allow damping the rise of retail prices in commodity markets of the country, without resorting to the application of administrative measures, such as limiting the rate of return.

It makes sense to plan the maximum income for the parent enterprise when selling finished products when it is about vertically integrated companies with transfer pricing At the same time, the price of components for the parent enterprise should be planned based on enterprise suppliers profitability, which would not be burdensome for the parent enterprise. And only after the sale of finished products, suppliers should receive their share of earnings.

Fig. 6.9 Dependence of the VAT rate on profitability



It was shown that the parent enterprise receives the maximum income when the rate of gross value-added in relation to the cost of components is optimal. This allows maintaining the product competitiveness at price and directing the corporate profits to innovative development.

The introduction of a non-linear taxation mechanism for supplier enterprises that are not part of a vertically integrated structure allows for hold of the selling prices of components.

The method allows maintaining high price competitiveness of products and profitability providing the opportunity for innovative development.

Chapter 7
Information and Analytical Systems and Simulation Models for Efficiency Assessment and Decision Making in the Field of New Competencies Development

7.1 Basic Approaches to Efficacy Assessment of New Competencies to Ensure a Sustainable Organization Development

Under modern conditions, high-tech corporations should implement various programs to ensure sustainable development. As already noted, the main mechanism to ensure the sustainable development is production competitiveness management at high-tech corporate enterprises. Competitiveness management is required to ensure sustainability and production stability in conditions of risks and uncertainty. Nevertheless, it is required to have accurate estimates of the economic efficiency of concrete measures being planned at existing high-tech corporation enterprises. In view of this, there arises the task of new competencies efficacy assessment which would become the driving force to raise competitiveness.

The general objective of high-tech companies is to develop measures to increase productivity, reduce self-costs and increase economic stability in conditions of budget cuts. When planning these measures it is required to take into account that certain segments of economy are regulated ones in which the State acts both as the sole customer and a regulator. The fundamental decisions on which technologies should develop, the amounts of funding to be allocated for certain programs, etc., are the result of a complex, largely politicized interaction between State bodies. Therefore, the variety of official corrections based on the assumption that the given sector is operated under the rules of the common competitive market, are unlikely to lead to the claimed objectives to improve the efficiency and productivity.

In experts' opinion to be more competitive in existing markets, companies should use complex, integrated approaches to the creation of new key competencies. The goal is to meet the key competitive requirements—to be more cost-effective, thrifty and flexible, consistently ensuring high performance and quality of projects. The given requirements should be fulfilled in the conditions of changing global events, volatile markets and technological progress in both civil and defense spheres to

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ensure a high economic sustainability. A company's stability is its sustainability against any internal and external impacts. "The more stable is a state of the object which is less susceptible to changes, deviations from the previous state under the equal external influences." Therefore, the choice of an optimum alternative for new competencies development should take into account its influence on the corporation's sustainability.

Let us construct an optimal structure calculation model for the flagship and pioneer products, the latter being produced on the basis of new competencies and pioneer products influence on the company's financial sustainability in the conditions of limited funding.

Let us introduce the following signs:

$x(t) = (x_0(t), x_1(t), \ldots, x_n(t))$	row-vector of production volumes by type in the t-time period, where $x_0(t)$ is the flagship volume (in units) in the corresponding period; $\{x_1(t), \ldots, x_n(t)\}$ is a set of pioneer production in the corresponding period;
$p(t) = (p_0(t), p_1(t), \ldots, p_n(t))$	row-vector of manufacturer's prices in the t-time period;
$w(t) = (w_0(t), w_1(t), \ldots, w_n(t))$	row-vector of manufacturing costs per unit in the t-time period in the enterprise operating interval $T = [1, 2, \ldots, N]$.

Let introduce operating functions which express the relationship between manufacturing and the output as:

$$X_l = F(x_l(t)), l = 0, 1, \ldots, n, \tag{7.1}$$

then the gross profit for each type of product $\Pi(x_l(t))$ will amount to

$$\Pi(x_l(t)) = p_l F(x_l(t)) - [w_l \cdot x_l(t) + c_0], l = 0, 1, \ldots, n, \tag{7.2}$$

where $TR(x_l(t), p_l) = p_l F(x_l(t))$ is turnover in money terms;

$TC(x_l(t), w_l) = w_l \cdot x_l(t) + c_0$—cost summaries for l-th production type which include variables: manufacturing costs$w_l \cdot x_l(t)$, and constant costs c_0.

The total gross profit for N periods of time for all the types of production will amount to

$$\Pi_\Sigma(x_l(t)) = \sum_{t=1}^{N} \sum_{l=0}^{n} \Pi(x_l(t)). \tag{7.3}$$

Let introduce the selling rate of both flagship and pioneer products $q_l = \frac{dx_l(t)}{dp_l}$ which is dependent on sell prices, as differentiable functions:

$$q_l = q(x_l(t), p_l), l = 0, 1, \ldots, n, \tag{7.4}$$

In the simplest case the financial stability of an enterprise operating is connected with the fulfillment of the condition below:

$$\Pi_{\Sigma}(T) \geq \Pi_*, \tag{7.5}$$

where Π_* is the minimum gross profit in money terms which corresponds to production volume breakeven point $x_l^0(t)$, i.e. when $\Pi(x_l(t)) = 0$ and when the enterprise can continue in operation in the interval of $T = [1, 2, \ldots, N]$.

Let

$$\gamma = \frac{\Pi_{\Sigma}(T) - \Pi_*}{\Pi_*}. \tag{7.6}$$

be a dimensionless criterion of financial stability.

Then assessing an enterprise's stability we will consider:

- The enterprise is stable if $\gamma \geq 1$;
- The enterprise is not stable if $\gamma \in [0, \ 1]$;
- The enterprise is losing money if $\gamma \leq 0$.

Let reduce the choice of the optimal structure of basic and diversified products in the conditions of limited funding and taking into account the demand functions q_l (7.1) to a multiobjective optimization task:

$$\left(\Pi(x_0(t)), \Pi(x_1(t)), \ldots, \Pi(x_n(t))\right) \rightarrow \max_{(x_0, x_1, \ldots, x_n)} \tag{7.7}$$

when the following conditions are fulfilled:

(a) The gross profit should cover all the costs

$$\sum_{t=1}^{N} \sum_{l=0}^{n} \Pi(x_l(t)) \geq \Pi_*, \tag{7.8}$$

(b) Manufacturing costs for defense together with diversified products should not exceed the specified value of C^* for the T-period, where

$$\sum_{t=1}^{N} \sum_{l=0}^{n} w_l x_l(t)) \leq C^*. \tag{7.9}$$

It can be assumed that an effective solution for (7.1)–(7.9) can be found only if the enterprise can be stable only because of its optimal new-competencies development policy.

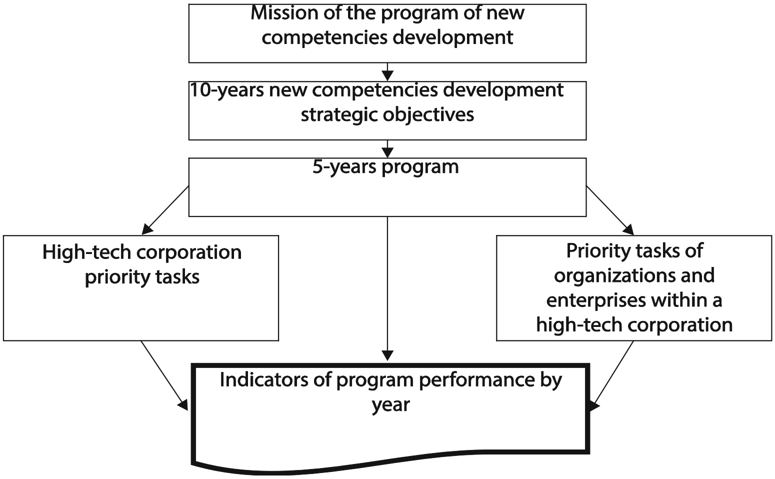

Fig. 7.1 Managing the competencies development of organizations and enterprises within a high-tech corporation

This approach can be integrated into the general methodology of competitiveness management, covering all the necessary information, knowledge and competencies. The general structure of this process is shown in Fig. 7.1.

The experience of the successful expansion of product lines of the largest high-tech corporations shows that the methodology relied on the achievements in the field of research and development, unique equipment parks, attraction of highly qualified scientific, design, engineering and operating personnel into new divisions.

The levels of the technologies applied, the core competencies and the products science-intensity during the decision-making on the program implementation were high enough for these corporations to ensure their competitiveness in emerging markets for some certain time.

On the other hand, new competencies provided an opportunity to block the risk of declines in state funding and, even in this case, to raise the level of capitalization.

Therefore, determining the existing core competencies and a deep and systematic study of material, technological and personnel capacities to master new certain high-tech products must precede developing new competencies.

The success of measures for the new production competencies development requires the assessment of many activity indicators of corporations and enterprises, the most important of which we consider the volume and the nature of their assets. According to the most approximate model-based estimations, when it is about achieving competitiveness versus world leaders, the real value of the assets of even relatively successful corporations should be raised at least 2.5 times.

Important aspects of the measures above are to determine opportunities of structure optimization, the possibility to reduce production costs for certain corporations and enterprises and to achieve a labor productivity level which would allow them to be competitive on the high-tech markets.

The comprehensive assessment of new competencies development readiness level is set by convention, since dozens of different other variables affect this key indicator, e.g. economic and political risks, investment attractiveness, depreciation of production assets, the prices for products, human capital, organizational design, management efficiency, and many others.

Therefore, to fully understand the readiness level and making appropriate decisions on new competencies development, it is proposed to use the algorithms of multicriterial evaluation and multimodel approach. Within the latter a few simulation models by production sector are developed Then these models are combined within a metamodel.

Within the framework of our approach, the economic and mathematical statement of the problem of assessment and optimal allocation of resources for new competencies development by holdings and enterprises is given. It is based on dynamic programming models which take into account the specifics of multi-product activities and the production of dual-purpose products.

As a result, the possibility to estimate and forecast the development of certain holdings and enterprises within a given time period time increases dramatically. At the same time, the task is to work out a specific or unique theory for the organization, which theory includes a unifying knowledge of how combinations of internal and external assets and opportunities can create competitive production.

In Fig. 7.2 is presented the graphical interface of the system-dynamic model, on which various factors interact as variables. These factors determine the competencies development management efficiency.

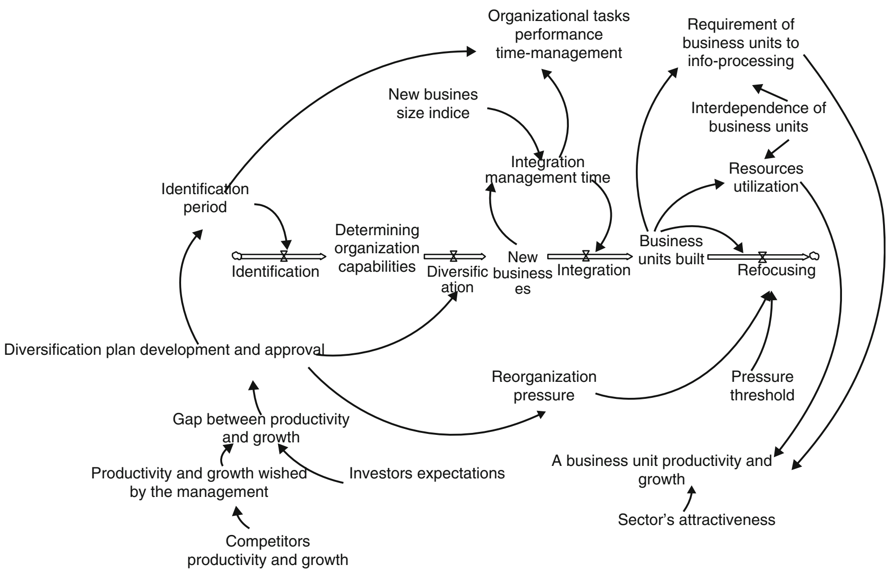

Fig. 7.2 Graphical notation of the system-dynamic model of managing competencies development process (designed with the use of Vensim simulation software)

The task of simulation is the construction of possible management effectiveness scenarios in the context of key factors analysis and the sensitivity of selected indicators, the time profiles and data volatility and assumptions about their interaction.

Comparative analysis and the process implementation efficiency assessment in terms of time and financial costs are based on author's methodology of multicriterial analysis and evaluation of the effectiveness of objects with a hierarchical structure of criteria and are in accordance with methodological principles of solving multicriterial tasks.

The methodology of multicriterial analysis is a set of methods and principles for solving the metatask of multicriterial analysis of companies activities efficiency. Metatask solving procedure can be represented in the form of solving successive subtasks of varying complexity. Solving the metatask of multicriterial evaluation of objects with a multilevel indicators structure is associated with three basic principles and relatively simple axioms. The principles of the system approach lying in the basis of the methodology are as follows:

– *The principle of decomposition* allows to structure (decompose) a complex problem (system, object, metatask) into a hierarchy of groups (subsystems, tasks, subgroups and so on);
– *The principle of multicriteria* means that the objects quality and efficiency evaluation tasks should be addressed as multicriterial ones;
– *The multi-model principle* assumes that the evaluation of a complex system (a multilevel object) can be achieved only on a complex of models reflecting various aspects of this system (multilevel object).
– The axioms of the methodology include the following provisions:
– *Axiom of homogeneity* assumes that the objects under evaluation should be homogeneous at each level of the hierarchy, i.e. comparable in terms of indicators and parameters;
– *The axiom of composition (synthesis)* is that generalized estimators of objects or the importance of higher-level indicators in the hierarchy depend on the contribution of objects estimates or the importance of indicators of lower levels.

In the applied sense, methodology of the multicriterial evaluation of competencies development performance in the sense of time and financial costs can be represented in the form of basic principles and axioms, requirements to methods under development, stages of solving problems of varying complexity to receive generalized estimations resulting scales and as a result to qualitatively or quantitatively distinguish objects depending on their efficiency.

It is necessary to evaluate objects in a uniform system of indicators used in a subject area. When developing the methodology of constructing multicriterial quantitative ratings, it is necessary to take into account a number of features specific to multicriterial analysis tasks: non-equilibrium of indicators (criteria) of quality and efficiency of objects (enterprises); multi-level structure of indicators of quality and efficiency of objects; a variety of measurement scales for objects; heterogeneity and nonlinearity of object estimates gradations.

Table 7.1 Derived performance indicators of production structures (million rubles)

Indicator	***В***—revenue	***П***—profit
К—capitalization	$\frac{B}{K} \cdot 100$—rate of return, %	$\frac{П}{K} \cdot 100$—return on asset, %
Ч—number of employees	$\frac{B}{Ч}$—labor productivity	$\frac{П}{Ч}$—labor profitability

Along with the specifications to the methods for solving the constructing a multicriterial rating being developed problem, the basic requirement is presented, it is: object comparability by their generalized (aggregated) estimates preferability in the root vertex of the hierarchical criteria structure, that is, the same regularity and comparability of objects in equivalent resulting scales.

In the tree hierarchical structure, lower-level criteria belonging to a same cluster are also meaningful. They can be of equal importance and also can be fairly quantified by experts. However, the specific criteria of different clusters contribute differently to higher levels criteria. To account for this contribution, it is necessary to quantify criteria meaningfulness among each other in terms of the importance at every level.

First we need to build a hierarchical tree of importance criteria and arrange them in descending order of meaningfulness at each level of the hierarchy.

The initial list of indicators is presented in Table 7.1.

Let's group together seven economic performance indicators of several diversified production structures into three groups and present them in the following orderly hierarchy:

$$F_0: \quad F_1 \succ F_2 \succ F_3; F_1: f_{11} \succ f_{12} \succ f_{13}; F_2: f_{21} \succ f_{22}; F_3: f_{31} \approx f_{32},$$

where F_0—is the composite index of economic activities of the diversified structures (root vertex);

F_1—is a group indicator of financial result of the diversified structures, it combines the following indicators: revenue—f_{11} in million dollars, profit—f_{12} in million dollars, capitalization—f_{13} in million dollars;

F_2—is a group indicator of financial efficiency, it includes: rate on return, %—f_{21}; return on asset, %—f_{22};

F_3—is a group indicator of labor efficiency, it includes: labor productivity—f_{31} in thousand dollars, labor profitability—f_{32} in thousand dollars.

Hierarchical 3-level tree of the importance criteria arranged in descending order of significance is presented in Fig. 7.3.

Using the multicriterial evaluation methodology, a comparative analysis of the production structures performance can be made based on the dynamics of indicators describing the main aspects of their activities in the period before the measures for the new competencies development and after them. Accordingly, multicriterial analysis of the specific holdings and enterprises economic status will help to justify the allocation of resources necessary to create new high-tech products and develop procedures for efficient resources allocating.

The success of each production structure can be ultimately assessed by the extent to which the "input" indicators (time and expended resources) reflect the costs of

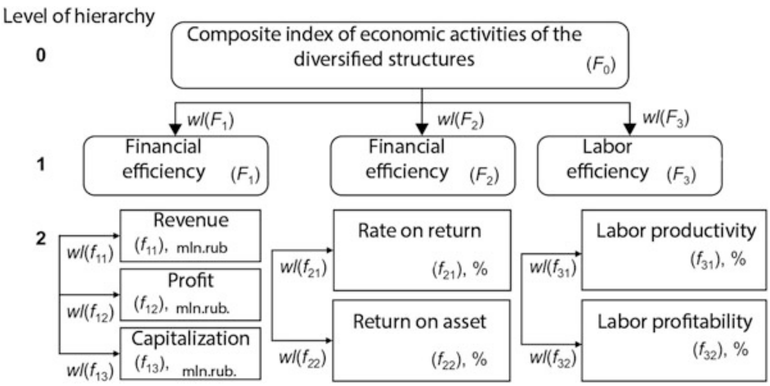

Fig. 7.3 Hierarchical tree of economic activity criteria of production structures arranged in descending order of significance

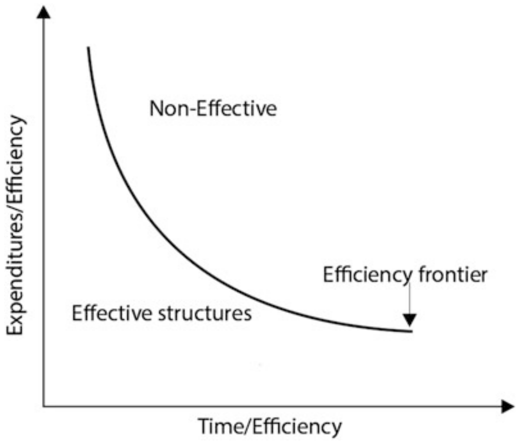

Fig. 7.4 Production structures efficiency frontier

achieving the desired result, measured by the "exit" indicators (performance or efficiency). A visual diagram of competencies development results (efficient frontier) shows how this very complex system is reduced to a relatively simple problem involving production structures economic indicators. In mathematical form, the efficiency can be hypothetically expressed as a function of the independent variables "time" and "resources", i.e. efficiency = f (time, resources).

Visualization in Fig. 7.4 shows that, using this function, the diversified structures efficiency may be represented as a function of time or resources.

Multicriterial analysis of high-tech holdings and enterprises economic status will help to justify the allocation of resources necessary to create high-tech products and develop procedures for efficient allocation of resources necessary for implementation of production development and its performance assessment in terms of time and financial expenditures. With the use of multicriterial analysis the following particular tasks are solved, as shown in Fig. 7.5.

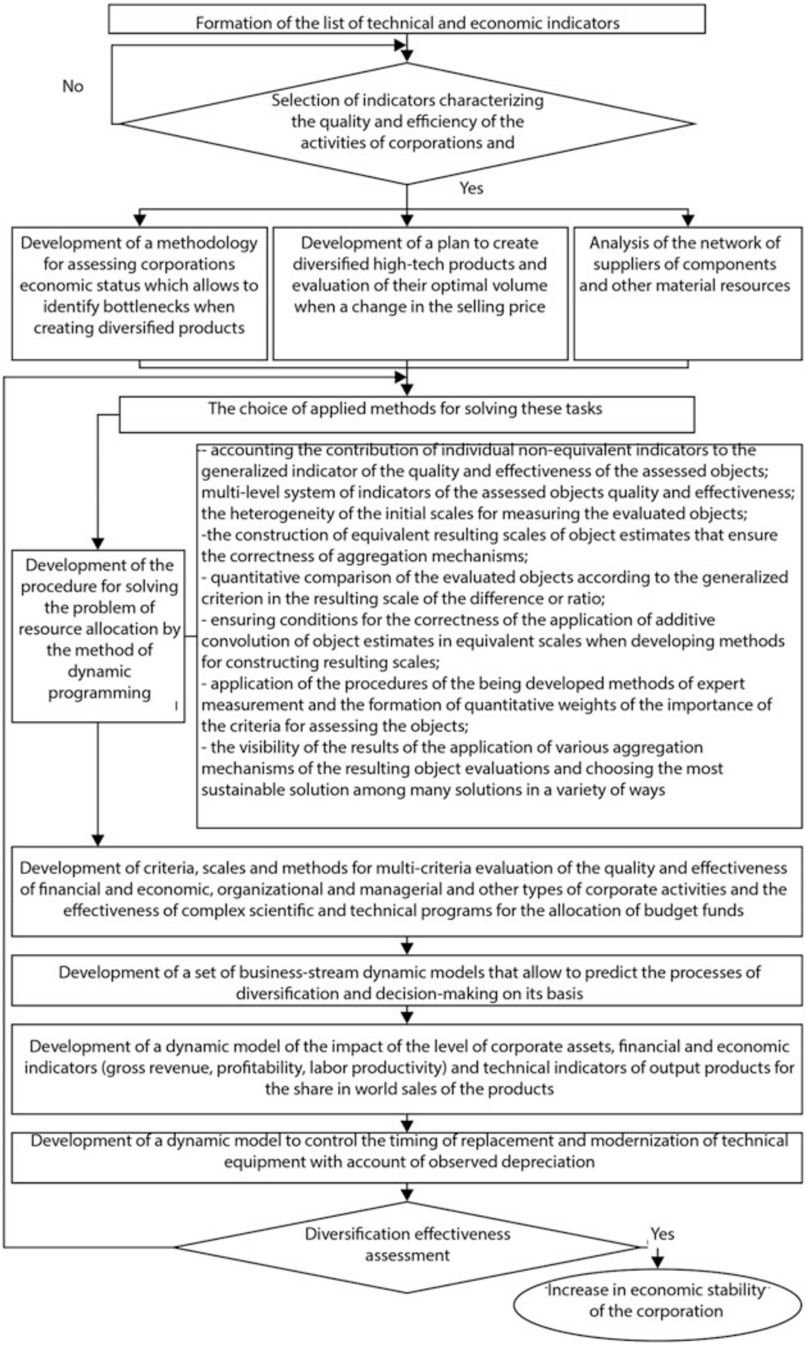

Fig. 7.5 Algorithm for solving particular tasks of the competencies development

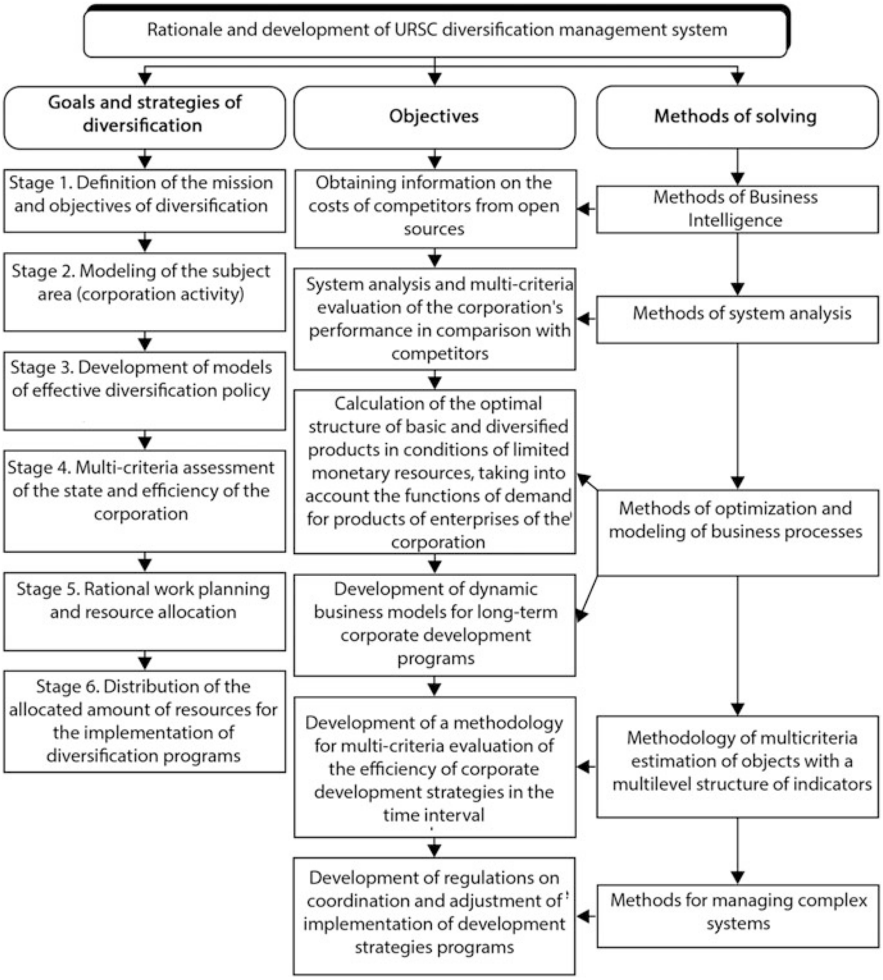

Fig. 7.6 The scheme for creating a competencies development management system in high-tech industries

From our point of view, the process of creating in high-tech holdings and enterprises the competencies development management system, which takes into account the dynamics of the above factors, should include a number of stages, tasks and methods for their solution, the aggregate of which is shown in Fig. 7.6.

The high-tech industries competencies development management system (SUD) is designed to determine the production development policy on the basis of measurable and verifiable measures on the efficacy of using the resources allocated to create high-tech new products and develop procedures for their optimal allocation while ensuring the sustainability of the high-tech industries production base.

Within the framework of SUD, a number of programs are being created through which active cost management is organized by careful assessing of new products pricing factors, determining goals and indicators to reduce the production costs, and introducing certain methods to achieve them.

SUD provides the need for close coordination between developing industries by integrating planning, product development projects, technological development and product improvement, and identifying risks and threats in this field of activity. Achieving the goals will require identification and removal of certain barriers to commercialization of products and technologies, cooperation with small high-tech business.

SUD is called upon to identify the current and emerging technologies that can provide a significant competitive advantage for holdings and enterprises in promising high-tech markets for the period until 2030. This activity focuses on research and prioritization for various applications of technology, including innovative and breakthrough technologies, establishment of advantages of R&D investments.

On the other hand, SUD will identify and eliminate unproductive or constraining regulations, inappropriate or contrary to the policy of diversification methods and management practices. The ultimate goal of these measures is to reduce the costs and time of producing high-tech new products and to ensure an acceptable level of competitiveness in the relevant markets.

7.2 Economic and Mathematical Methods for Assessing New Competencies Efficiency to Provide for Sustainable Development of the Industry

Today sustainable development is one of drastic issues for various sectors of economy, not excluding the high-tech. With proper planning, the sustainable development program can become one of the engines for the development of a high-tech corporation. A high-tech corporation sustainable development program can be implemented in several key directions. First of all, this is using own capacities for manufacturing the components, hardware, etc., which currently purchased abroad. On the other hand, temporary free production areas may be loaded with non-core products, in demand both on the domestic and foreign markets. Here, the sustainable development is closely linked to the diversification of the industry.

In the current economic conditions, an enterprise can implement projects to launch new types of products by using such financial resources as available net profit, commercial banks' credit funds and budgetary funds. In this regard, there are significant risks associated with the circulation of a large amount of financial resources. These risks may be associated with low solvency of the enterprise (both the principal amount of the loan and interest are to be paid), bad faith of components suppliers, delays in budget financing and other negative factors. Also, it may be necessary to partially re-equip production for manufacturing new types of products which may involve the need for financial expenditures. In the context of limited financial resources and to reduce the adverse impact of the identified risk factors, the following scheme in the form of a network schedule can be proposed; the elements of the scheme are enterprises (for example, within one corporation), which are interested, firstly, in the uninterrupted production and, secondly, in the sale of the whole volume of finished products.

The explanation of the scheme is given in the example. Suppose that enterprises of a high-tech corporation need components of their own production. Let's say this enterprise is equipped with modern equipment that can produce, for example, printed circuit boards and electric motors. The enterprise is considering a certain device as a prospective type of products to improve economic sustainability. Let the necessary components for this device are a printed circuit board and an electric motor (both can be produced by the enterprise itself), as well as a plastic case (the enterprise does not produce it). The organization of plastic cases production requires a large investment with the use of credit funds (which implies a gradual return of the principal and interest to the bank). Another way to solve the problem is to purchase the cases from a third-party enterprise. But in this case, there are risks associated with the time of circulation of funds and other negative factors. An alternative mechanism is the creation of a network of enterprises within which the role of financial resources in the exchange of goods and services will be minimized. For example, a network of two enterprises can be built based on a corporate structure. The first enterprise is already the described enterprise which is going to produce the device. Another enterprise, for example, has a plastic production. It is capable of producing plastic cases of sufficient complexity, but is compelled to purchase printed circuit boards abroad. These two enterprises can be combined into a network, and the equivalent exchange of products between them will be established without direct use of financial resources.

When creating such a network, the problem arises of providing financial guarantees to an enterprise that produces plastic cases for a situation when the products exchange for one reason or another does not take place. Such guarantees can be provided by including two financial institutions in the scheme. The first institution is a branch reserve bank, which is a structural unit at the level of the industry (corporation, ministry) to which the first enterprise belongs. Such a reserve bank may have various assets (finance, real estate, intellectual property). The branch reserve bank evaluates the project to produce the device at the first enterprise in terms of its feasibility and market demand. If the assessment is positive, the branch reserve bank issues a guarantee document (for example, a bill of exchange), the value of which fully covers the financial risks for the second enterprise. But in order to start work, the second enterprise needs guarantees of a commercial bank. This can be achieved through the avalization of the reserve bank's bill by the commercial bank. In this case, the second enterprise receives the commercial bank's guarantees. Avalization is carried out by commercial banks for a commission, representing a certain percentage of the value of a bill. Expenses for bank aval are fixed in this case and are not subject to various risks.

In general, a network of enterprises that is built to implement a project consists of a number of enterprises that are interested in the production and marketing of their products. In this case, the bill of the branch reserve bank covers the financial risks of all the enterprises involved in the project implementation.

Further, we demonstrate modern methods that allow evaluating the sustainable development efficiency.

Methods related to the calculation of the labor content of the production operations necessary to carry out such programs have been the main ones in solving this kind of tasks for a long time. In modern economic conditions, involving rational use of financial resources, high requirements for technological level and competitiveness, as well as orientation to the maximum possible use of the components and materials of domestic origin, new effective methods of assessing the ability of enterprises to implement the proposed import substitution program are needed.

The evaluation of the import substitution efficiency is of a qualitative nature and reflects the degree of the enterprises ability to implement the program. These degrees can be expressed by the following definitions:

– The enterprise has sufficient technical level and qualified personnel to implement the sustainable development program;
– The enterprise basically has sufficient technical level, cooperation with other enterprises is required for certain technological operations (training of a number of specialists, etc.);
– The enterprises is able to implement the sustainable development program provided that the production is seriously modernized and a large number of specialists are employed;
– The enterprise is not ready to implement the sustainable development program.

The mentioned definitions can be supplemented by intermediate characteristics that more accurately reflect the degree of enterprise readiness to implement the sustainable development program.

A modern enterprise manufacturing high tech products is a complex system with a multilevel structure with vertical and horizontal connections between its elements. There are administrative, production, research and other elements within the enterprise. Each division performs its function and uses various resources (financial, labor, etc.) to conduct its activities. На деятельность организации оказывают влияние различные факторы, которые могут носить как внутренний, так и внешний характер. External factors are related to the overall development of the state economy, the competitiveness of the industry, state support for the industry and for the given enterprise. Such factors cannot be managed at the enterprise level. External factors, as a rule, are common for all enterprises of the industry. In this regard, the problem of identifying and assessing the factors that characterize the internal state of an enterprise (financial, technical, etc.) is topical for solving the task of assessing its technical readiness for the implementation of the import substitution program. Internal factors form the internal micro-environment of the organization, which will facilitate or hinder the successful implementation of the sustainable development program. Next, we will propose a system of indicators characterizing the organization microenvironment, as well as economic and mathematical tools for quantifying the relevant factors.

We will assess the internal state of the enterprise using the following groups of factors:

- Financial and economic factors;
- Research factors;
- Engineering and manufacturing factors;
- Manpower sufficiency factors;
- Information and methodological factors;
- Organizational and management factors.

A sustainable development program to be implemented at the high-tech enterprise is associated, as a rule, with the manufacture of a certain product or a product line. Each specific product, which is the object of a sustainable development program, has a set of technical and technological features that can be used to assess the conformity of production to the order on manufacturing this product. Information about the enterprise can be obtained from the Works Certificate of the enterprise. This document, in particular, contains information on the availability and use of production capacities, fixed assets availability and their performance indicators, main energy resources consumption, organizational and technical level of production, availability of manpower and use of employees working time. Another source of information for assessing the enterprise is the financial statements, which reflect the main financial indicators of the enterprise (balance sheet profit, profitability, working capital turnover, operating profit, etc.).

Below we describe briefly the groups of factors characterizing the enterprise internal microenvironment, and we will show how these factors can be correlated with the sustainable development program features.

The first group of factors characterizes the *financial and economic state* of the enterprise. These factors characterize the availability and use of available financial resources. When analyzing financial and economic factors, it is necessary to assess the provision of the current production and economic activities with relevant resources, that is, the efficiency of using financial resources in production. Assessment of the financial and economic state of the enterprise can be made on based on standard economic indicators of the enterprise:

- The working capital ratio;
- Stock turnover period;
- Working capital to current assets ratio;
- Financial leverage;
- Equity to total assets ratio;
- Debt to fixed assets ratio;
- Asset turnover ratio;
- Asset turnover period;
- Return on assets;
- Return on sales;
- Profit margin.

Of course, the given list of criteria is not exhaustive and can be changed or supplemented in each specific case of production assessment.

Each of the presented indicators of the financial and economic state of the enterprise is a quantitative estimate, which is obtained using standard formulas and is based on financial statements. So the working capital ratio, for example, is the ratio of the volume of working assets to the short-term debt of the enterprise.

Let each enterprise is characterized by a vector of financial and economic indicators:

$$FE^i = \begin{pmatrix} x_1^i \\ x_2^i \\ \vdots \\ x_N^i \end{pmatrix},$$

where i is the ordinal number of the enterprise;

N is the number of financial and economic indicators.

It is expedient to normalize the components of vectors according to the following rule:

$$\tilde{x}_j = \max_i x_j^i,$$
$$\bar{x}_j^i = \frac{x_j^i}{\tilde{x}_j},$$

where $\bar{x}_j^i$—is the resulting normalized component.

Further, it is possible to rank the normalized vectors that characterize the financial and economic state of the enterprise. When ranking, one can calculate the distance between the reference (unit) vector and the vector being examined. The series of the obtained values will correspond to the sequence of the enterprises ranks. One of standard distance function may be used when ranking:

1. The linear distance:

$$d_{l_{ij}} = \sum_{l=1}^{m} \left| x_i^l - x_j^l \right|.$$

2. The Euclidean distance:

$$d_{E_{ij}} = \sqrt{\sum_{l=1}^{m} \left(x_i^l - x_j^l \right)^2}.$$

The Euclidean distance is the most popular measure of the proximity of two vector objects, since it is the (geometric) distance in a multidimensional space.

3. The square of the Euclidean distance:

$$d^2_{E_{ij}} = \sum_{l=1}^{m} \left(x_i^l - x_j^l\right)^2.$$

The square of the Euclidean distance is another way of determining the distance between objects. This method consists in squaring of the ordinary Euclidean distance in order to assign greater weights to the objects most distant from each other.

4. Minkowski generalized power distance:

$$d_{P_{ij}} = \left(\sum_{l=1}^{m} \left(x_i^l - x_j^l\right)^P\right)^{\frac{1}{P}}.$$

Minkowski distance is a generalization of the Euclidean distance and can be of interest in theoretical studies and in various economic and mathematical models. In its essence, this is a universal mathematical metric.

5. Chebyshev distance:

$$d_{ij} = \max_{1 \le i,j \le l} \left|x_i - x_j\right|.$$

This distance distinguishes between two objects, even if they differ from each other in just one of any attribute.

6. Manhattan distance:

$$d_H\left(x_i, x_j\right) = \sum_{l=1}^{k} \left|x_i^l - x_j^l\right|.$$

This metric is also sometimes called the Hamming, or "city-block" distance. It is the average of the differences of the distances by the coordinates. In most cases this measure corresponds to the results obtained using the Euclidean metric. But the effect of individual runs for the Manhattan distance is less than when using the Euclidean distance. This is achieved by the fact that the coordinates in this metric are not squared.

Note that the weights of financial and economic attributes can be used. In this case, the components of the normalized vectors must be multiplied by the weights of the corresponding attributes, after which it is necessary to perform the ranking by comparing the vectors with the reference one in accordance to the selected metric.

The next group of factors characterizes the *scientific and research sector* of the enterprise. This group of factors is of particular interest, since the implementation of the import substitution program for the science-intensive production is usually associated with a complex of research works. Research factors characterize the enterprise's knowledge and experience in the science-intensive production development. The characteristics of the enterprise scientific and research potential when assessing the level of production for allocating the import substitution program are:

- Availability of both scientific schools and individual specialists engaged in research and development in areas close to the subject of the import substitution program;
- The existence of stable links with leading scientific organizations and centers whose activities are related to the subject of the import substitution program;
- Presence of intellectual property and rights to it in the form of patents for inventions, industrial designs, certificates for utility models, software, trademarks and service marks, etc.;
- The share of experimental and research facilities, machines and equipment associated with technological innovation in the total value of all production and technological machines and equipment.

Only the last indicator can be quantified. The availability of patents, certificates, etc., should be evaluated qualitatively, since the number of patents and certificates does not always correspond adequately to the innovative and technological level of the enterprise. Other characteristics of the research potential should be assessed qualitatively on the basis of a certain system of parameters developed in the line with the import substitution program. The processing of such a system of parameters can be efficiently performed using an automated inference system, which will be presented in the next paragraph. The results of the work of such a system is the enterprise qualitative assessment, reflecting the conformity of scientific and technical potential to the tasks solved in the framework of operational activities.

One of the most important is the group of factors that characterizes the *production and technological potential* of the enterprise. These factors characterize the state of production assets and infrastructure, the possession of technologies necessary for the import substitution program implementation, the availability of free production capacities sufficient for the implementation of the sustainable development program, etc. The estimation of the production and technological potential can be carried out on the following group of factors:

- Possession of the technologies necessary for the implementation of the production program;
- Availability of all necessary technological processing stages;
- The enterprise's ability to master new equipment and modern technologies;
- Presence of necessary production capacities;
- The state of production assets;
- The conformity of the production equipment with the required standards (for example, international);
- The availability of cooperation with partner enterprises in the field of production technologies consistent with the sustainable development program.

These characteristics can be supplemented by others more closely related to the sustainable development program.

Most of these characteristics can also be given a qualitative assessment. Thus, it is possible to conclude that all necessary technological processing stages are available by checking the availability of each stage. The characteristic "Availability of the necessary production capacities" also assumes the assessment of capacity. A conclusion about the sufficiency of various production capacities is made based on this assessment. For example, products, which are planned to be produced as part of the import substitution program, presuppose the existence of five-layer printed circuit boards. Assessment of the availability of the necessary production capacities in this case involves, firstly, the verification of the enterprise for the availability of appropriate equipment and, secondly, the assessment of the working time fund for this equipment. Such an analysis should be carried out for all major production operations, which are necessary in the framework of the sustainable development program. As a result, for each technological processing stage, a table should be formed that would reflect the configuration and production capacity of the equipment to be involved in the import substitution program implementation. This table may also reflect equipment features, such as obsolescence, difficulties in obtaining tools and outfitting, etc. The task of assessing the production and technological potential of an enterprise can also be successfully solved with the help of an automated inference system.

The group of factors characterizing the workforce capacity of the enterprise is closely related to the factors of production and technological potential. These factors characterize the level of professional training of specialists working at different levels of the enterprise organizational structure. Thus, the availability of the necessary labor resources is estimated in the same way as the availability of the necessary production capacities. If necessary, one can assess the enterprise's need to recruit new specialists to implement the production program. Another important characteristic of the workforce capacity is the availability of opportunities for the enterprise to manage the talents. Workforce capacity characteristics are also of a qualitative nature, and the corresponding conclusions can be made with the help of a logical inference system.

Information and methodological factors characterize the degree of automation of the technological process, the use of automated information systems, modern design tools, etc. For example, the use of the digital production model is an information and methodological factor.

Finally, managerial and organizational factors characterize the efficiency of organization and management of production. First, it is necessary to analyze the efficiency of interaction between structural elements of the enterprise and try to identify strengths and weaknesses. Secondly, it is necessary to assess the enterprise on grounds such as "the existence of a sustainable development strategy," "the introduction of innovative management mechanisms," etc. The analysis can also be carried out using an automated inference system.

So, we examined the main groups of indicators, which can help to assess the level of production from the point of view of the possibility to launch a new products release program. In Table 7.2 shows an indicative set of characteristics that can be assessed.

Table 7.2 Characteristics for assessing the level of production

Group of characteristics	Characteristics
Financial and economic	The working capital ratio; stock turnover period; working capital to current assets ratio; financial leverage; equity to total assets ratio; debt to fixed assets ratio; asset turnover ratio; asset turnover period; return on assets; return on sales; profit margin, etc.
Research	Availability of both scientific schools and individual specialists; the existence of stable links with leading scientific organizations and centers; presence of intellectual property and rights to it; the share of experimental and research facilities, machines and equipment associated with technological innovation in the total value of all production and technological machines and equipment, etc.
Production and technological	Possession of modern technologies; availability of all necessary technological processing stages; the enterprise's ability to master new equipment and modern technologies; presence of necessary production capacities; the state of production assets; the conformity of the production equipment with the required standards (for example, international); the availability of cooperation with partner enterprises in the field of production technologies consistent with the production program, etc.
Workforce capacity	The level of professional training of specialists working at different levels of the enterprise organizational structure; the availability of the necessary labor resources; the enterprise's need to recruit new specialists to execute the order; the availability of opportunities for the enterprise to manage the talents, etc.
Information and methodological	The degree of automation of the technological process, the use of various information systems, implementation of the digital production concept, etc.
Organizational and managerial	The efficiency of interaction between structural elements of the enterprise, the existence of a sustainable development strategy, the existence of innovative management mechanisms, etc.

Conclusion on the readiness of the enterprise to implement the sustainable development program is based on the compliance of the enterprise with the many features of this program. Let's give examples of possible features of a product being designed under the new types of products release program; the features usually differ depending on the type of products and customers requirements:

– The need for high-precision metal processing with certain tolerances;
– The need to use five-layer printed circuit boards;
– The need to install special devices;
– The level of requirements to components and spare parts.

It is often impossible to give an unambiguous answer (such as "meets" or "does not meet") about the compliance of the enterprise with one or another import substitution program feature. For example, compliance with the provision on "the need for high-precision processing" can be expressed in addition to the options "meets" or "does not meet" with the options "meets, subject to modernization of the production site" or "it is possible to order an operation from another enterprise".

Briefly describe the classical economic model for determining the technical level of production based on accounting for the labor content of manufacturing products. This analysis is based on a comparison of the technical level of production and the technical level of the technology underlying the sustainable development program.

A fairly simple mathematical model is used to assess the technical level of the enterprise's production:

$$T_{el} = T_p \times K_p + T_т \times K_т + T_o \times K_o + T_i \times K_i,$$

where T_{el} is the technical level of enterprise (workshop, site, organizational unit);

T_p is the technical level of the product;

T_o is the technical level of management;

T_i is the technical level of the *i*-th indicator, for example, the technical level of production readiness or the technical level of design and engineering automation;

K_p, $K_т$, K_o, K_i are coefficients characterizing the significance of T_p, $T_т$, T_o, T_i in the overall assessment and determined by experts.

Indicators T_p, $T_т$, T_o, T_i can be generally defined by the formula:

$$T_i = \sum \Pi_i j_i.$$

Now let's show how to determine the technical level of the technology according to the following formula:

$$T_т = \sum \Pi_т j_i,$$

where $\Pi_т$ is the indicator of the level of technology;

j_i is the weight of the indicator.

The following indicators can be used to define the level of technology:

- Π_i^g—the labor content of manufactured products;
- Π_i^m—the material content of manufactured products;
- Π_i^n—the power inputs for production;
- Π_i^a—the level of automation of technological processes.

Each enterprise in market conditions defines its controlled indicators, so the range of indicators can be expanded or minimized. Substituting the values of these indicators in the above formula, taking into account the j_i defined by experts, it is possible to obtain values characterizing the technical level of the technology.

Based on the comparison of the technical level of enterprise production and the level of technology required to implement the import substitution program, the conclusion of possibility to implement it at the enterprise can be made.

One of modern methods for making a qualitative conclusion based on the judgments system is an automated system of logical inference (an expert system) capable of formulating such a conclusion with high reliability.

An automated system of logical inference is usually understood as a program complex, which in a certain sense replaces an expert in the field. The use of expert systems allows on one hand to automate the procedure for analyzing the situation by experts, and on the other hand to make this procedure formal. The use of formal methods in assessing the import substitution efficiency allows ensuring sustainable development of the enterprise. The basis of the architecture of the automated logical inference system is the separation of knowledge inherent in the system, and algorithms for their processing.

The structure of an automated logical inference system includes such necessary components as the knowledge base, the output system and the user interface.

In general, the algorithm of the expert system works as follows:

1. Receiving answers from the user;
2. Primary processing of answers, obtaining the facts of the expert system;
3. Processing of facts using the knowledge base, making individual conclusions based on the facts obtained;
4. Making the expert system conclusion from the facts established in step 3.

Here is an example that demonstrates the logical inference, which can be obtained from the expert system user responses. So, let be needed to make a conclusion on the possibility of manufacturing at the enterprise a device with a five-layer board and plastic case of a special shape, as part of the import substitution program. The expert system offers the following questions:

Q1: Does the enterprise have the capacity to produce five-layer circuit boards?
Q2: Does the enterprise have its own hardware components?
Q3: Does the enterprise have the capacity to manufacture plastic cases?

Let the expert give the following answers to these questions (he chose from the list of answers):

A1: The enterprise has the capacity to produce printed boards;
A2: Import hardware components are required;
A3: The enterprise has the technology of plastic moulding for the production of cases.

Based on the answers received, the fact of the expert system of the following character can be formulated:

F1: It is possible to produce the device if the components are purchased abroad.

Note that the facts of the expert system are also pre-formulated, and the choice of a concrete fact is conditioned by the work of logical inference functions of the expert system. When answering questions of the expert system, the user did not need knowledge of programming or specialized economic-mathematical models and methods. The expert was guided only by knowledge of the technical level of the production being assessed.

Further, as a result of the expert system work, a system of facts is formed on the basis of the user's answers, after which the final conclusion is formulated using the rules for processing the facts.

Table 7.3 The expert's answers and degree of certainty

Answer	A1	A2	A3
Degree of certainty, p_i	0.75	0.8	1

Next, consider the basic mathematical models and approaches used for logical inference in expert systems.

The use of certainty factors (likelihood) and weights for the answers and facts The degree of certainty characterizes the measure of the conclusion likelihood initially set by the expert. The possibility of applying this rule is determined by the satisfaction of conditions with a certain level of veracity. That is, the statements veracity contained in the premise of the rule can also be fuzzy, for example, because of previous inference steps or because of the inaccuracy of the source of the answers. After applying such rules to existing answers, a more general rule is formed, which also includes the assessment of the veracity of compliance with conditions.

For example, in the expert system, certainty factors can take values in the range from 0 to 1. The value of one indicates the full certainty of the expert in his answer, and zero value is the degree of his extreme uncertainty. Suppose that the expert gave answers to the questions and indicated the degree of his certainty (Table 7.3).

The degree of certainty in answering questions determines the degree of likelihood in formulating the fact of the expert system. Various mathematical approaches to determine the degree of likelihood of the fact p can be used:

$$p = \min_i p_i,$$

$$p = \frac{1}{N}\sum_{i=1}^{N} p_i,$$

$$p = \sqrt[N]{p_1 \cdot p_2 \cdot \cdots \cdot p_N}.$$

For the example described, the likelihood degree of the fact in the first case is 0.75, in the second—0.85, in the third—0.84.

A certain degree of likelihood also corresponds to the final conclusion.

Widespread in economic models is the practice of assigning weighting factors to objects. The predetermined weights correspond to answers and facts. These coefficients reflect the contribution of the answers to the formulation of the fact and the contribution of the facts to the formulation of the final conclusion. These coefficients also affect the determination of the degree of likelihood of the fact and the final conclusion. Thus, the weights of the answers w_i and the degree of certainty of the expert together determine the degree of likelihood of the fact:

$$p = f(w_i, p_i).$$

The form of the function f can be defined in a special way when building an expert system.

Methods of probability theory

The provisions of probability theory can be efficiently used to represent the uncertainty of knowledge. The necessary tools can be based on the methods of probability theory. By definition, the conditional probability of an event d in the presence of some fact s is the probability that event d occurs, provided that the event s has occurred. For example, a conditional probability is the probability that an enterprise will be able to obtain the necessary five-layer board (d) if it has the necessary equipment (a partner enterprise capable of making payments, etc.) (s). The following formula is used to calculate the conditional probability:

$$P(d|s) = \frac{P(d \wedge s)}{P(s)}.$$

There are also the following conditional probability properties, knowledge of which helps to get the probability value in practice:

$$P(d \wedge s) = P(s) \cdot P(d|s),$$
$$P(d \wedge s) = P(d) \cdot P(s|d).$$

The Bayesian rule for calculating the conditional probability of events is based on these properties:

$$P(d|s) = \frac{P(s|d) \cdot P(d)}{P(s)}.$$

This rule allows you to determine the probability $P(d|s)$ of occurrence of an event d, provided that the event s has occurred through known conditional probability $P(s|d)$. The probability theory suggests ways of calculating the conditional probability when considering a variety of different conditions:

$$P(d|s_1 \wedge \cdots \wedge s_k) = \frac{P(s_1 \wedge \cdots \wedge s_k|d) \cdot P(d)}{P(s_1 \wedge \cdots \wedge s_k)}.$$

The conditions s themselves can be both dependent on each other, and independent.

Thus, the conditional probability formula approach offers one more way to determine the degrees of likelihood of answers and facts. Let's consider an example: Let the event d is "the enterprise is capable of producing a five-layer circuit board", the event s is "the enterprise has the necessary equipment and qualified personnel to produce the printed circuit boards". The desired probability of the event $P(d)$ can be found from the formula:

$$P(d) = \frac{P(d|s) \cdot P(s)}{P(s|d)}.$$

Let the expert defined the following values for probabilities (Table 7.4):

Table 7.4 The source data for the conditional probability formula

Probability	$P(d\|s)$	$P(s)$	$P(s\|d)$
The value	0.9	0.8	1

The value of $P(s) = 0.8$ can reflect, for example, the fact that the qualifications of the staff are not sufficient to produce five-layer printed circuit boards. The desired value of the probability of manufacturing the five-layer printed circuit board for given initial data $P(d) = 0.72$. This value can be interpreted as the degree of likelihood of the received answer about the possibility of producing the necessary printed circuit boards.

Models based on the theory of fuzzy sets and fuzzy logic

Since the expert system works with the initial data received from users, it becomes possible to use the powerful tools of fuzzy mathematics. With the help of fuzzy mathematics, one can get fuzzy conclusions that can more adequately describe the actual information.

Experts in evaluating certain characteristics, often use knowledge based not on information about specific examples of objects, data, relationships, but rather operate generalized categories of concepts: object classes, aggregates of judgments, etc. The methods of solving problems, therefore, should include the stage of classification of data or knowledge. That is, specific instances of objects, signals, etc. are considered as representatives of more general classes, categories. But in real situations, there are rarely objects that exactly correspond to a particular category or class. In a particular instance, some of the features may be present, and the other part may be absent. Thus, the belonging of this object to any class is fuzzy. Such phenomena can be efficiently described with the methods of fuzzy mathematics.

Classical set theory is based on Boolean, binary logic. The belonging of an object to a class can take a positive value if the object enters into a set, or negative value in the opposite case. After the appearance of the notion of a fuzzy set, ordinary sets also began to be called strictly deterministic. It is the inherent determinism in the definition of categories in the classical set theory that became the source of problems when trying to apply it to describe fuzzy categories.

Let's consider the fuzzy approach on an example. Take the notion of "resolution class" of the technological process of a microcircuit manufacturing as a fuzzy category. The question arises, which chip can be considered corresponding to the required technological process. In the classical theory, the set A of microcircuits can be formed either by enumeration of concrete representatives of a given class, or by introducing into consideration a characteristic function *f* such that for any object *x*:

$$f(x) = TRUE \Leftrightarrow x \in A.$$

We can say that each element of the set of microcircuits is more or less typical for this category. Therefore, with the help of some function, one can express the degree of belonging of an element to a set. Let the function $f(x)$ is defined on the interval [0, 1]. Then, if for the object x the function $f(x) = 1$ then this object is definitely a member of the set, and if $f(x) = 0$ then it definitely is not a member of the set. All intermediate values of $f(x)$ express the degree of belonging to the set. In the example with microcircuits, a function is required that operates with the resolution of the technological process. It can, for example, be defined in such a way that $f(90\,нм) = 0$ and $f(40\,нм) = 1$, and all intermediate values are represented by some monotone curve having values in the interval [0, 1]. Logical conclusions when working with fuzzy objects are built on the basis of the fuzzy logic apparatus, which takes into account features associated with the uncertainty of objects.

Game-theoretic approach in constructing an expert conclusion

Let the problem of expert inference be considered when answering a question. Let the expert system offer several options for answering the question. Denote these answers as follows:

$$A_i, \quad i = 1, 2, \ldots, N.$$

Thus, we will consider N different options for answering the question. Formulation of the final answer to the question is connected with determining the degree of compliance of the answer with the real situation at the enterprise. We will use dimensionless quantities of the compliance degree in the mathematical formulation of the problem. Let the compliance of each variant of the answer with the situation at the enterprise be denoted by the value

$$x_i, \quad i = 1, 2, \ldots, N.$$

These values satisfy the following condition:

$$x_i \geq 0, \quad i = 1, 2, \ldots, N.$$

In this notation, we will consider a vector quantity:

$$x = \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{pmatrix}.$$

We say that the result of the answer to the question depends on the degree of compliance of the answer with the real situation at the enterprise. In a more general formulation of the problem we will consider a functional dependence

$$A = A(x).$$

The expert's choice of a specific answer to the question in this formulation of the problem corresponds to the concepts of strategy in game theory. Denote by

$$S_i, \quad i = 1, 2, \ldots, N,$$

sets of ways to select an expert answer, which correspond to the options considered. According to the game-theoretic approach, we will assume that the choice of a specific way of answering the question

$$s_i \in S_i, \quad i = 1, 2, \ldots, N,$$

is carried out in the interest of the i-th option. Thus, there is a conflict of interest in determining the degree of compliance of the options of answers to the questions $x$with the actual state of affairs at the enterprise which corresponds to the task of multicriterial optimization.

The formal relationship between managerial decisions and allocations of funding is set with a special function:

$$D : S_1 \times S_2 \times \cdots \times S_N \to R^N.$$

Using this function

$$x = D(s_1, s_2, \ldots, s_N)$$

is calculated that is used in the computation of functions A_i as follows:

$$A_i = A_i(D(s_1, s_2, \ldots, s_N)).$$

Thus, we obtain a formal definition of the game

$$\Gamma = \left\langle (S_i)_{i=1}^N, (A_i)_{i=1}^N \right\rangle$$

where $(S_i)_{i=1}^N$ are sets of strategies of the players, and $(A_i)_{i=1}^N$ are the pay-off functions. By the solution of the game is usually understood the state of equilibrium, which is determined on the basis of various principles. The most common principle of equilibrium is the Nash equilibrium. Nash equilibrium means a combination of strategies in which none of the players benefit from changing their strategy. Although the Nash equilibrium is quite common, it is difficult to use this principle to solve multicriterial optimization problems. First, as a rule, there is no Nash equilibrium in pure strategies, and secondly, this principle is based on equality of players. In multicriterial optimization problems, it is usually assumed that there is a given hierarchy of optimized criteria. Therefore, to find the solution of the game formulated above, it is necessary to proceed from the Stackelberg equilibrium. This equilibrium is based on the presence of preference criteria. The pay-off function when using the game-theoretic approach to determining the expert inference corresponds to the most appropriate answer from the point of view of the actual situation at the enterprise for which the production program feasibility is assessed.

Comparison of various schemes and plans for the implementation of a sustainable development program based on the proposed algorithm will allow choosing the program whose successful implementation is most probable.

Thus, this paragraph presents approaches and models with the help of which the most efficient schemes for implementing a sustainable development program for enterprises of a high-tech corporation can be chosen, which will contribute to the sustainable development of the entire industry.

7.3 The Architecture of Information and Analytical Platforms for the Implementation of Simulation Models for Assessing New Competencies

The information and analysis systems for the implementation of simulation models for assessing new competencies should meet high requirements for the quality of the system's construction and should ensure:

- The completeness of the information for each of the elements in the information flow system. Completeness can be defined as the ratio of the information received by the element to the one that was requested or needed to assess new competencies. Because of the relativity of knowledge about information flows, it will most likely not be possible to achieve 100% information completeness. An important factor is also that with increasing the completeness ratio, there is an increase in costs for management and employees and reduction in the management processes efficiency;
- The usefulness and value of the information. As noted earlier, the data are meaningful for the manager only when they can be used to make managerial decisions. Therefore, information flows in the system for the implementation of simulation models for assessing new competencies being developed should be personalized, i.e. directed to specific executives and officers;
- The accuracy and reliability of the information. If appraisal decisions are made on the basis of system data that are unreliable or do not meet the accuracy requirements, then the risk of error and making the wrong decision increases;
- The timeliness of the information receipt. If the information is not received on time, the control body will be idle at the very moment when the control object is especially in need of control;
- The aggregability of the information. Aggregation is understood as the rational distribution of information by levels of the management hierarchy. The higher levels of management should receive more generalized information, the lower levels—more detailed information. An example of the need for aggregation of information can be the fact that generalized statistical data is important for making decisions at the level of a high-tech corporation's top-management while at the level of a laboratory head within a separate enterprise, operational data, data on dynamics are needed;

- The relevance of the information. In the conditions of a market economy and a continuous technical and technological update, information is becoming obsolete at a faster pace. Therefore, when making decisions, the age of information and its relevance for the current task should be taken into account;
- Cost-effectiveness and efficiency of information processing. The effectiveness of the information subsystem can be assessed by comparing the management results with the costs of collecting, accumulating, storing, processing, converting and transmitting information. In addition, the automated information system must meet a number of technical requirements, such as:
  - Performance: speed of input, search and processing the information;
  - Reliable protection against unauthorized data access;
  - Registration of personnel actions;
  - User-friendly workstation interface;
  - The possibility to enhance the system;
  - Integration with the modules used in the data transmission system;
  - The possibility to convert data from previously used formats to the new system;
  - High reliability of work. The information system of the enterprise includes the subjects of communication, channels and media, as well as hardware and software.

The main sense of the open systems approach is the simplification of the computing systems complexing due to international and national standardization of hardware and software interfaces. The main driving force behind the use of the open systems concept in the automated system of simulation models for assessing import substitution and diversification was the ubiquitous transition to the use of local computer networks and the possibility of hardware and software complexing provided by this transition. In view of the rapid development of global communications technologies, open systems are assuming even greater importance and scope.

Practical support of system and application software in the automated system for assessing import substitution and diversification is a standardized operating system.

Technologies and standards of open systems provide a real and proven possibility of producing system and application software with the properties of mobility and interoperability. The property of mobility assumes a relative simplicity of transporting the software system in a wide range of hardware and software that meet the standards. Interoperability implies the possibility simplify the new software systems complexing using ready-made components with standard interfaces.

A common solution to the problem of mobility of an automated system for assessing import substitution and diversification based on the client-server architecture is to rely on software packages that implement Remote Procedure Call (RPC) protocols. When using such tools, accessing the service at the remote node looks like a normal procedure call. The RPC tools, which naturally contain all the information about the specifics of the LAN equipment and network protocols, translate the call into a sequence of network interactions. Thus, the specificity of the network environment and protocols is hidden from the application programmer.

When calling a remote procedure, RPC programs convert the client data formats to intermediate machine-independent formats and then convert to server data formats. When transmitting response parameters, similar transformations are performed.

The main ideas of the remote procedure call mechanism, which is the technological basis of the client-server architecture, are the following:

(a) In many cases, the interaction of processes is clearly asymmetric. One of the processes (the "client") requests from another process ("server") some service and does not continue the execution until this service is provided (and until the client process receives the corresponding results). Obviously, this interaction mode is semantically equivalent to calling the procedure, and the desire to formalize it syntactically in accordance with that fact is natural.
(b) Network operating. The portability property allows, in particular, extreme simplifying the creation of "operationally homogeneous" networks with heterogeneous computers. However, there remains the problem of different data representation in computers of different architectures (often floating-point numbers are represented in different ways, different order of placing bytes in the computer word is used, etc.) Therefore, RPC implements automatic conversion of data formats when processes running on heterogeneous computers are interacting.

Hereinafter, the term "database server" will be used to denote the entire database, based on the client-server architecture, including both server and client parts, which are designed to store and provide access to databases.

Let us dwell in more detail on the conceptual moments of organization of access to the database in which the core of the system is located.

Access to the database from the application program or user is done by accessing the client part of the system. The main interface between the client and server parts is the SQL database language.

This language is essentially the current standard of the DBMS interface in open systems. Collective name SQL-server refers to all SQL-based database servers, thus, observing precautions when programming, one can create applied information systems that are mobile in the class of SQL-servers.

Database servers, whose interface is based solely on SQL, have their advantages and disadvantages. The obvious advantage is the standard interface. In the limit, which is hardly fully achievable, the client parts of any SQL-oriented DBMS could work with any SQL server, regardless of who produced it.

However, here the developer of an automated system for assessing import substitution and diversification will face the following drawback. With such a high level of interface between the client and server parts of the system, there are too few DBMS programs on the client side. This is normal if a low-capacity workstation is used on the client side. But if the client computer has sufficient capacity, then often there is a desire to assign more database management functions to it unloading the server which is the bottleneck of the entire system.

One of the promising ways to improve the quality of the database of the system for implementing simulation models for the import substitution and diversification assessment is a flexible system configuration in which the functions allocation between the client and user parts of the DBMS is defined when installing the system.

A typical database server is responsible for the following functions:

- Maintaining a logically consistent set of files;
- Ensuring the database manipulation language;
- Information recovery after various kinds of failures;
- Organization of a really parallel operation of several users.

Direct data management in external memory includes providing necessary external memory structures both for storing immediate data of the database and for service purposes, for example, to speed up access to data in some cases (usually indexes are used for this). In some implementations of database servers, the capabilities of existing file systems are actively used, in others the work is done up to the level of external memory devices. But we emphasize that in developed DBMS users in any case do not have to know whether the DBMS uses a file system, and if it does, then how are the files organized. In particular, the DBMS supports its own system of naming database objects.

Database servers in accordance with the developed concept work with databases of considerable size; at least this size is usually much larger than the available RAM. It is clear that if, when accessing any data element, an exchange with external memory is performed, the entire system will work with the speed of the external memory device. Practically the only way to actually increase this speed is to buffer the data in RAM. At the same time, even if the operating system performs system-wide buffering (as in the case of UNIX OS), this is not enough for the purposes of the DBMS, which has much more information about the usefulness of buffering one or another part of the database. Therefore, it is necessary to use the DBMS own set of RAM buffers with its own discipline for changing the buffers.

It is also possible to apply the DBMS direction oriented to the permanent presence in the operative memory of the entire database. This direction is based on the assumption that in the future the amount of computer RAM can be so large that it will be no need to worry about buffering.

Another requirement for the organization of the database is the ability to manage transactions. It is assumed that the transaction is a sequence of operations over the database, considered by the DBMS as a whole. Either the transaction is successful, and the DBMS commits changes made to the database by this transaction in the external memory, or none of these changes are reflected in the state of the database. The notion of transaction is necessary to maintain the logical integrity of the database.

Thus, the maintenance of the transaction mechanism is a prerequisite for the use of DBMS in a system implementing simulation models of import substitution and diversification assessment in multi-user databases.

The fact that each transaction begins with an integral state of the database and completes leaving the database in the integral state, makes it very convenient to use the concept of transaction as a measure of user activity in relation to the database. With the appropriate management of parallel transactions on the part of the DBMS, each user can in principle feel the only user of the database. It should be noted that with the real work of the system implementing simulation models of import substitution and diversification assessment in some cases users of multi-user databases can feel the presence of their colleagues.

Partly, in the basis of the being developed infologic model of the information system implementing simulation models of import substitution and diversification assessment lie the principles common with OLAP-applications (On-Line Analytical Processing). Therefore, it is convenient to use the conceptual developments of such applications in the information system being developed.

The term OLAP-applications (On-Line Analytical Processing), usually characterizes the principles of building Decision Support Systems (DSS), Data Warehouses, Data Mining systems. These systems are designed for finding dependencies between data. Our database, like OLAP-applications, is characterized by the following principles:

Adding new data to the system is relatively rare with loading large blocks (for example, quarterly sales data from the OLAP-application).

The data added to the system are usually never deleted.

Before loading, the data undergo various “cleanup” procedures, due to the fact that data from many sources with different presentation formats for the same concepts can come to one system, the data may be incorrect or erroneous.

The queries to the system are ad hoc and, as a rule, rather complicated. Very often a new query is formulated by the analyst to refine the result of the previous query.

Query performance is important, but not crucial.

As was already indicated above, the “client-server” class was chosen as the basis of the architectural solution for the information system implementing simulation models of the import substitution and diversification assessment. And this decision is virtually the only possible in the task of the import substitution and diversification assessment. Show the key features and advantages of this class of architectural solutions.

As the conceptual model suggests (Fig. 7.7), the client-server environment consists of clients and servers. Client machines should be single-user personal computers or workstations that provide an end-user friendly interface. End users can be divided into two classes, the operator and the administrator. The “operator” class of users should include specialists responsible for adding operational reports and monitoring their quality at specific enterprises of a high-tech corporation. The class “administrator” should include people who can view and analyze the results of import substitution and diversification automatic assessment. As you can see, the functional and the user interface must be radically different.

The client station should have a user-friendly graphical interface that assumes that there are windows and a mouse, and an interface with touch screens of tablets is possible.

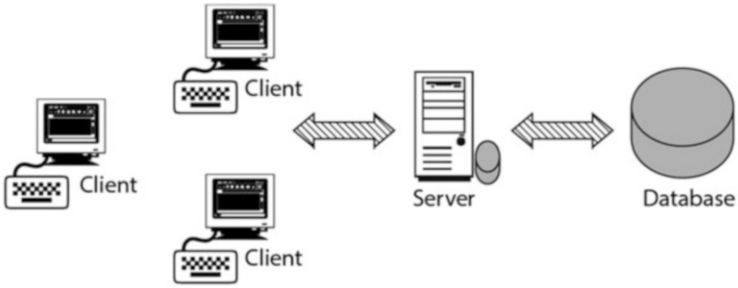

Fig. 7.7 Schematic representation of the architecture of the information system implementing simulation models of import substitution and diversification assessment

Client applications involve ease of use and familiar tools, spreadsheets for example. Each server in a client-server environment provides customers with a set of services. Database server managing the relational database will be the basis of the server in the client-server architecture of our information system.

A high-performance server provides multiple clients to share access to the same database. In addition to clients and servers, the client-server environment includes a network. The client-server computing model by definition is a distributed one.

Users, applications and resources are located on different computers and connected by a common local, global or inter- network.

Some of characteristics of this architecture are:

In client-server applications, much attention is paid to creating a user-friendly interface on the client machine. Thus, the user receives full control over the schedule and mode of operation of the computer, and departmental level managers are able to respond to local problems.

Although the applications are distributed ones, centralized corporate databases are used the information system for automatic assessment of import substitution and diversification. This allows the management of a high-tech corporation or people who are members of the "administrator" group to retain complete control over investments in information systems, as well as to ensure the complete connectivity of all systems. At the same time, this configuration relieves the various enterprises of the industry from the overhead of managing complex computer systems, but allows them choosing the types of machines and interfaces needed to access the data.

Using this approach, it is possible to use modular systems. This means that the user is given a wider choice of products and greater freedom in combining equipment from different manufacturers.

A computer network is a key link in this architecture. Therefore, the issues of network administration and network security when working with information systems of this type take precedence.

Thus, by summarizing the above, it is possible to form a table of advantages and disadvantages of the information system implementing simulation models of import substitution and diversification assessment based on the proposed architecture (Table 7.5).

Table 7.5 Advantages and disadvantages of conceptual approaches to building an information system for automatic assessment of import substitution and diversification

System characteristics	The value
Advantages	
A network of small powerful machines	If one machine fails, the project of automated assessment of import substitution and diversification in enterprises will still be able to continue work
Powerful computer complexes	The system provides the power to perform work without monopolizing resources. End users have enough capacity for local work
Some workstations are as powerful as mainframes, but their cost is an order of magnitude lower	By providing computing power for less money, the system makes more efficient use of the resources of the industry as a whole
Open systems	Hardware, software and services can be purchased from different suppliers
Ease of system build-up	The system is easy to upgrade as needs change
Individual working environment for each individual enterprise	Ability to flexibly customize the user interface taking into account the specifics of each individual enterprise
Disadvantages	
Poor support	Due to the complexity of the connections, errors can occur that are more difficult to correct than in simply-connected information systems
Lack of service tools	Due to the uniqueness of each major client-server project the service tools will have to be developed and maintained additionally
Need for training	Users belonging to the "operator" class must be trained in each enterprise for inclusion in the system implementing simulation models of import substitution and diversification assessment (due to the uniqueness of the user interface). However, it should be noted that this training is not difficult

The most important feature of the computational model of the presented system is the distribution of applied tasks between clients and servers. An illustration of the general case is shown in Fig. 7.8. Both on the client and on the server, the underlying software is, of course, the operating system. The hardware platforms and operating systems of clients and servers may differ. In fact, different types of client and server platforms and operating systems can be used in a single environment. However, these differences do not matter if the server and client use the same communication protocols and support the same applications.

The interaction between the client and the server is provided by the communication software. Examples of such software are the TCP/IP protocol sets, the OSI protocols, and various proprietary architectures, such as SNA.

Of course, the purpose of all this support software (protocols and operating system) is to provide a base for distributed applications. In the ideal case, the application's function should be distributed between the client and the server in such a way that the computing and network resources are used optimally, and users

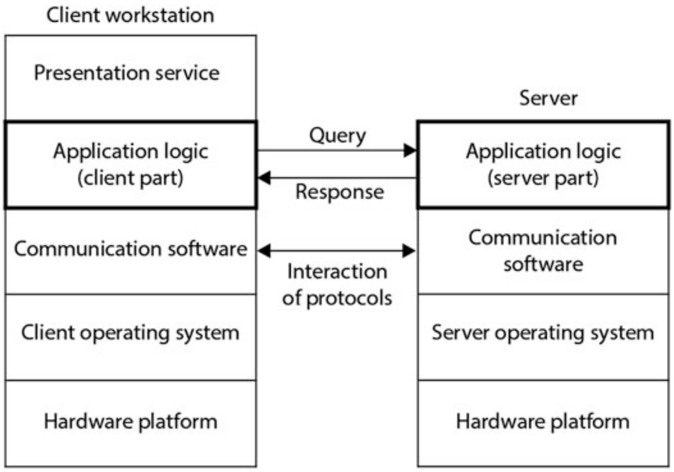

Fig. 7.8 The general architecture of an automated system implementing simulation models for assessing new competencies

get the best opportunities for performing various tasks and collaborative work. In some cases, for this, it may be necessary that the most of software would run on the server, while in other cases most of the logic may be implemented on the client.

An essential factor of proper work of the system and the proper assessment of new competencies is the method of user interaction with the system, that is, the user interface of the client machine is of great importance. In most client-server systems, the Graphical User Interface (GUI) is given very serious attention: it should be simple and convenient, but at the same time powerful and flexible. Thus, the presentation service module of the workstation can be considered responsible for a user-friendly interface with distributed applications.

In accordance with the conceptual model, we divide client computers into two different groups:

1. Client computers of the Operator class;
2. Client computers of the Administrator class.

These client application groups correspond to two groups of users. The first group collects information about the financial parameters of the specific enterprises of the corporation and loads it into the system during the reporting period.

The second group of users considers the analysis and evaluation of the system performance to be the main purpose of communicating with the system implementing simulation models for assessing new competencies. The goals, tasks and functions of these two groups of users are different, so the applications for them will be different. In addition, it is logical to take into account this significant difference among other things in the architectural structure of applications, so that the final application would be as reliable and effective as possible. In the future, we consider the general architecture of the application as an architectural scheme of its two constituent parts.

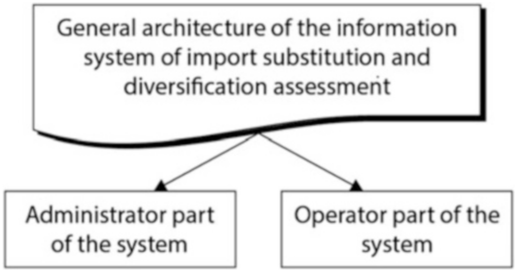

Fig. 7.9 The architecture of the import substitution and diversification assessment system

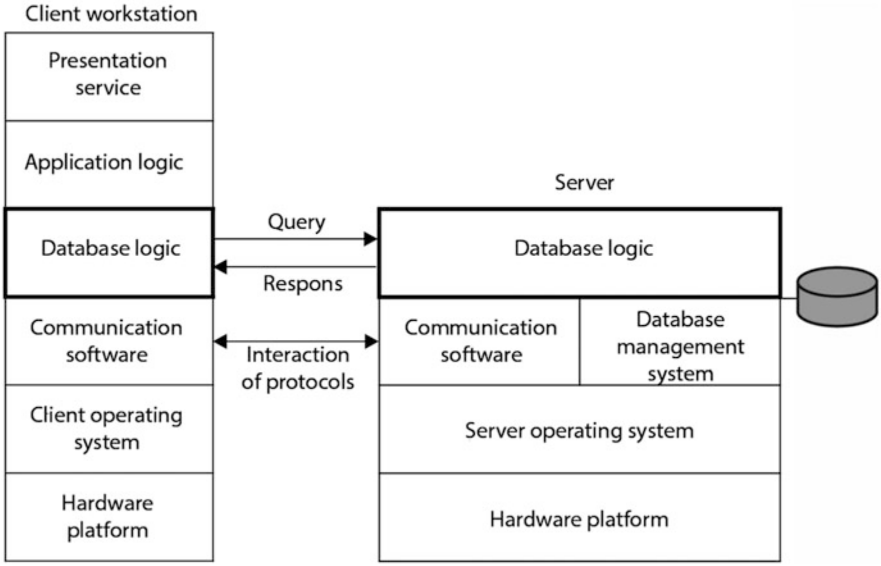

Fig. 7.10 The general architecture of the automated system for assessing new competencies integrated with database management (the operator part)

In accordance with the scheme shown in Fig. 7.9 the whole system can be considered as an entity consisting of two disjoint parts (the intersection is only in the data area).

Let's consider in detail the interaction of the system with the database server. The server is responsible for database management. Different applications that use the database can be located on client machines. A special software connects the client and the server, allowing the client to perform queries and get access to the database. A popular example of such logic is the Structured Query Language (SQL).

In Fig. 7.10 presents the general architecture of the automated system for assessing new competencies with a detailed description of the scheme of interaction of the common information system with database management systems. The

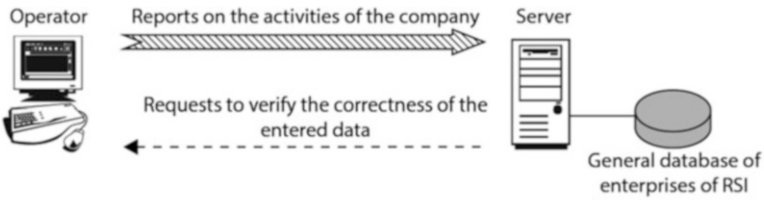

Fig. 7.11 The scheme of interaction of the Operator class client machine with the database server

architecture shown in Fig. 7.10 assumes that all application logic, programs for processing and analyzing data, is located on the client side, whereas the server is only concerned with managing the database. This organization of work is possible only for client applications of the Operator class.

Consider the advantages of this architecture organization:

- A large amount of work is done with the database for sorting and searching for data. This requires a large disk or disk array, a high-speed central processing unit and a high-speed I/O architecture. Such power is not needed on a single-user workstation or on a personal computer.
- Moving a file with a million entries to a client machine would be too heavy a burden on the network. Thus, it is not enough for the server to simply access the records on behalf of the client. The server should have database logic that would allow it performing search operations on behalf of the client.

Such an architectural approach is perfectly suited for the organization of client-server interaction within the Operator class.

The main operation that users need to perform on client machines is the recording of data during the data arrays reporting period; the size of arrays depends both on the specifics of the implementation of the information system for assessing new competencies at enterprises of a high-tech corporation and on the specifics of individual enterprises in the industry. Below is the diagram (Fig. 7.11) of the interaction between the clients of the Operator class and the data server.

It is important to note that the load on the computer network of the automated system for assessing new competencies at enterprises of a high-tech corporation is highly uneven. The main load on the computer network occurs during the reporting period, when each operator will add data on the main and additional parameters of individual enterprises into the database. The rest of the time, the main operator's work will be the reading from the database of the information about the enterprise, which was earlier entered into the system for assessing import substitution and diversification with the purpose of monitoring and analyzing these data. Elimination of errors in previously entered data is also possible.

In Fig. 7.11 shows the interaction of the client machines of the Operator class with the database server; the width of the arrows in the figure characterizes the width of the channel at peak loads.

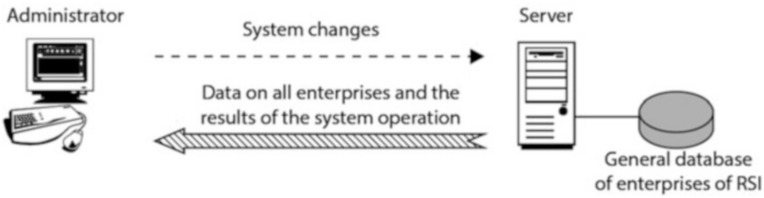

Fig. 7.12 The scheme of interaction of the Administrator class client machine with the database server

This scheme has a technical feature: in the case when the operator needs to evaluate and analyze the large amount of data entered, he will need to make a request, which returns a large amount of data. But the reading channel with a large bandwidth does not make sense. First, such a task contradicts the principles of the infologic model of the being developed system for assessing new competencies; secondly, it contradicts the principles of client-server applications organization. To perform this operation, it is necessary to transfer part of the logic to the server part of the system; however, this task will only be relevant for the Administrator class clients who have the ability to view and analyze the entire amount of data for expert evaluation of the efficiency and control of the automated system.

Let's take a closer look at the diagram of the interaction between client machines of the Administrator class and the database server of the system for assessing new competencies in a high-tech corporation (Fig. 7.12).

In Fig. 7.12 is a functional diagram of the interaction of client machines of the Administrator class and the database server. As you can see, in this case the main load on the computer network of the information system is created by the flow of requests to read information from the database. Much weaker flow is seen in the data record because, as a rule, the functions of clients of the Administrator class will be associated with monitoring the current state of the system and obtaining the results of its operating.

The client computers of the Administrator class have special software installed. It connects the client and the server, allowing the client to perform queries and get access to the database. A popular example of such logic is the Structured Query Language (SQL).

In Fig. 7.13 presents the general architecture of the automated system import substitution and diversification assessment in a high-tech corporation with a detailed description of the scheme of interaction of the common information system with database management systems. The architecture shown in Fig. 7.13 implies a solution that is partially the opposite of what was presented in the operator's part: here all the application logic—software for processing and analyzing data, as well as database management are located on the server side, while only the presentation service is on the client side. This view can vary greatly depending on the requirements of various administrators—people making decisions about the use of simulation models to assess new competencies.

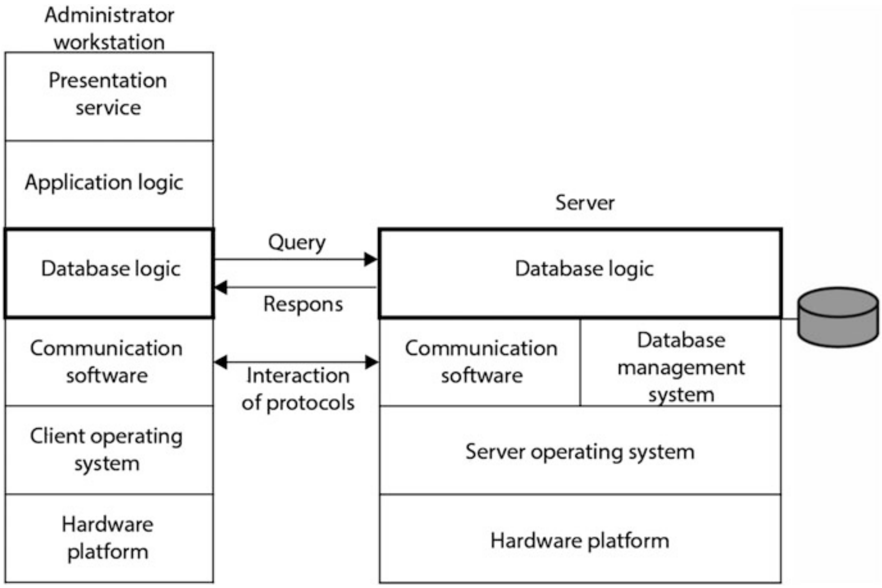

Fig. 7.13 Architecture of the automated system for assessing new competencies in a high-tech corporation integrated with database management (the administrator part)

Consider the advantages of this architecture organization:

- In the database, the server performs a large amount of work on sorting, searching and analyzing data in accordance with the mathematical model of analyzing the new competencies of a high-tech corporation. This requires a large disk or disk array, a high-speed central processing unit and a high-speed I/O architecture. Such capabilities are not needed on a single-user workstation or on a personal computer that belongs to a user of the Administrator class
- Moving a file with a million entries to a client machine would be too heavy a burden on the network. Thus, the server should provide a data access interface for computers of the Administrator class. Thanks to this interface, the server, having database logic, will be able to perform search operations on behalf of the client.

The quantitative size of the user groups “Administrator” and “Operator” can be estimated based on the tasks that are faced by the automated system for assessing new competencies. The number of users of the application group “Operator” is limited to the number of reporting units in the industry and the number of people responsible for filling out reporting information in the system. The number of users of the “Administrator” user group depends on the number of people who will use the systems to analyze the overall assessment of new competencies in a high-tech corporation. Probably, their number will be less than the number of users of the group “Operator”, but comparable to it. Thus, the computing power that must be allocated to each subsystem will be approximately equal.

7.4 Simulation Methods for Practical Implementation of Models for Assessing the High-Tech Industry Sustainable Development Methods

Below we outline the basics of simulation modeling used in the current study.

When designing an algorithmic model (also called simulation), the process of the system's operation in the time interval is described, simulating the primitive phenomena that make up the process itself, preserving their sequence of execution and the logical structure in the time interval.

Simulation is also divided into static and deterministic. Static models simulate actions of random and uncertain factors with the use of random number generators. This simulation method was called a static modeling method. To date, this method is considered to be the most efficient method of studying complex systems, and sometimes practically the only available method of obtaining information about behavior at the stage of designing a hypothetical system.

The combination of modeling techniques allows combining the merits of analytical and algorithmic modeling. To build such combined modeling systems, a preliminary separation of the functioning process into its components is carried out. Analytical models are used where possible; in other cases algorithmic models are used.

Simulation modeling is the most powerful and multifaceted method of researching and evaluating the capabilities of mixed systems, whose operation depends on random factors. Such systems include high-tech corporation enterprises that operate in conditions of poorly controlled market relations.

Before embarking on the development of a mathematical model for assessing high-tech corporation sustainable development methods, let us define the main steps that must be taken to build a model.

Modeling involves the following tasks:

- Setting the goal of modeling;
- Building the conceptual model;
- Designing the algorithm model of the system, the formalization of the model;
- Creating a system model program;
- The model experiments plan;
- Implementation of the experiment plan (conduction of computer experiments);
- Analysis and interpretation of simulation results.

The conceptual model is an abstract model that defines the structure of the system, the peculiarity of the components and the cause-effect relationships that are essential for the goal-achieving.

Building the conceptual model consists of the following steps:

- Determining which type the system belongs to;
- Description of the characteristics of the workload, i.e. identification of parameters and variables of the model;
- Decomposition of the system.

When building a conceptual model, at the first stage, the necessary data are collected (based on working with technical documentation and relevant literature, conducting experiments, gathering expert information, etc.), and also hypothesizing the values of variables and parameters for which actual data can not be obtained. If the data obtained is sufficient to implement modeling, then they can be the basis for classifying the simulated system. Classes of systems will be discussed later.

During the study of the efficiency of the system functioning, a correct description of the requirements for its operating is particularly important. This is a presentation of the list and indicators of external factors that affect the executive subsystem used to achieve the purpose of the operation.

In this case, it is more rational to consider the workload that corresponds to a certain system in place of the criteria for carrying out the operation. A work load is a set of external influences that affect the efficient application of the presented system in the framework of the operation being performed. The description of the workload is a complex and important task, especially when it is necessary to describe the workload for a brand new projected system or when it is necessary to take into account the influence of random factors.

The division of the system into simpler tasks, or decomposition of the system, is carried out depending on the chosen level of detail of the model, the definition of which is performed according to three criteria:

– The objectives of modeling;
– The system information not being researched;
– The requirements for the reliability and accuracy of simulation results.

Levels of detail called strata, and the process of allocating levels called stratification.

From the point of view of efficiency, the detailing should be performed to a level where correlations between output parameters and input effects are known or can be obtained for each element of the system. For a more accurate model, it is necessary to increase the level of detail in the description of the system, but this will complicate the modeling process and increase the time spent on it. For example, when designing a discrete system, a more detailed description of it will lead to an increase in the number of different states of the system that are taken into account in the model, and this in turn leads to an inevitable increase in the volume of calculations. Choosing the level of the description of the system, it is advisable to adhere to this rule: the model should include all the parameters that provide the definition of the characteristics of the system, which are of interest to the researcher in the given time interval of its functioning, other parameters should be excluded from the model. During the simulation, one can use special criteria to assess the selected level of detail. The first of these is the ratio of the real time of operating to the simulation time (the amount of computer time that will be required to carry out the experiment). For example, with one and the same approach to computer modeling of 1 h of the system's operating it will take 3 min of computer time in one case, and 10 min in another, which means that in the second case the degree of detail of the description is higher (in the ratio 3:10).

The second criterion is the resolution of the model:

- By time, i.e. defining the shortest interval of model time between neighboring events;
- By the smallest identifiable portions of information that are represented in the model (for example, for computing systems, these can be a task, program, word or page).

The third criterion is the simulation of a different number of system states or events of different types. For components about which it is known or possible to assume that they have greater impact on the accuracy of the results, the degree of detail may be higher than for others. The stability of the model increases with increasing detail, but at the same time during the implementation of the model experiment, the machine time is also increased. The final stage in the conceptual model development is the compilation of a meaningful and complete description used as the main document characterizing the results of work at this stage.

Designing the system model algorithm

Design or development of the model algorithm consists of the following sub-steps:

- Building the scheme of the algorithm;
- Identification of the mathematical mapping;
- Validation of the algorithm.

To begin with, a generalized scheme of the modeling algorithm is developed that specifies the general order of the actions in the modeling of the process under study. After that a detailed scheme is created, where each element is transformed into a program operator. For combined models, analytical and simulation parts are developed; the analytical part is represented by explicit functions, and the simulation part is expressed in the form of a modeling algorithm. Verification of the algorithm allows to answer the question of how much the algorithm corresponds to the goal of modeling formulated in building the conceptual model.

Creating a system model program;

Creating or developing a computer program consists of the following sub-steps:

- Selection of computational tools;
- Programming;
- Validation of the program.

This stage begins with the choice of the type of computer and the simulation program or programming language. After the program has been compiled, its verification is carried out on a specific example. In this sub-step, in order for the model developer to correctly formulate the requirements for the reliability and accuracy of the simulation results, it is necessary to estimate the costs of machine time for calculating one implementation of the modeling process.

At the heart of the simulation is a statistical experiment, the implementation of which is really impossible without the use of modern computing tools, so any simulation model is a more or less complex software product.

Like any similar program, the simulation model can be created in any universal programming language, even in Assembler. Still, in the way of the developer in this case, the following difficulties arise:

– It is necessary to know not only the subject area of the system under study belongs, but also the programming language, moreover at a fairly high level (the required level directly depends on the degree of the model complexity);
– The creation of special procedures for providing a statistical experiment (unit step inputs generation, experiment planning, processing of results) takes more time and effort than the development of the model itself. Ultimately, this is another significant problem.

In many practical problems attention is drawn not only to the quantitative evaluation of the efficacy of the system, but also its behavior in different situations. For such tracing, the experimenter should have appropriate interfaces or "viewing windows" that could be closed when necessary, transferred to another location, edited in scale and form of the observed data presentation, etc., without waiting for the completion of the running experiment. The simulation model in this case is the source of the answer to the question: "what if . . ."

Implementation of such features in the universal programming language is not an easy task. At the moment, there is a fairly large number of software products that allow modeling processes. These packages include: Pilgrim, GPSS, Simplex and a number of others.

The described software products, as it was said, allow quick implementing of simulation models. However, the resulting models would have a number of shortcomings in comparison with models implemented in professional programming languages such as C# or C++. The main drawbacks of models implemented with the help of specialized packages include the inflexibility, i.e. significant complexity in making changes to the model, lack of fine-tuning. In addition, most specialized packages for designing simulation models have some built-in template, which is configured by the user. As a result, a lot of operations arise that work "by default", this fact can negatively affect the operation and use of the model. Thus, a not accounted variable and a default operation that worked correctly on the test cases can connect to the actual model and distort the correctness of the results. Also one of the disadvantages of specialized packages is their lower speed, in some cases significantly lower, compared to models implemented in professional languages.

In fact, all described shortcomings are a consequence of the universality of the approach, which allows creating software products quickly, sometimes without sufficient qualification. Models in professional languages of a lower level require significantly more accurate, painstaking and long work when creating a software product. However, in this case, the created model excludes the black box effect, when the developer using a tool barely understands how this tool works. The developer, and sometimes the end-user, is given absolute freedom in setting up the model and full control over its work.

For further explanation and model building will only use professional languages, to ensure maximum performance and full control of the model being used.

Planning and conducting computer experiments with the system model

This stage consists of the following parts:

- Planning machine experiment;
- Working computations;
- Demonstration of simulation results;
- Interpretation of simulation results;
- Recommendations to improve the mode of the system operation.

Before to start working computations, one need to make the plan for the experiment describing the combinations of indicators and variables. The main objective is to develop an optimal experiment plan which would make possible conducting a small number of tests and obtaining reliable data on the system operation patterns as the result. The final results of the simulation may be visualized as graphs, tables, charts, diagrams, etc. Basically, a simpler form is a table, and charts more clearly demonstrate the system modeling results. It is reasonable to provide output to the display and printer. The purpose of interpreting the results of modeling is to draw conclusions about the functioning of the original object on the basis of information obtained as a result of the machine experiment. Based on the analysis of simulation results, it is possible to make decisions that would allow the system operating most efficiently.

Simulation modeling is a numerical method for studying and analyzing systems and processes through a simulation algorithm.

Whenever a random factor affects the modeled process, its effect is simulated by means of a special draw game, or lottery. That is, one random implementation of the simulated process is constructed, which is one result of the experiment. On the basis of a single experiment, one cannot judge the regularities of the phenomenon under study, but after a large number of implementations, the average characteristics formed by models acquire the property of stability, which increases with the increase in the number of implementations.

Drawing is easy to perform through special programs—generators of random numbers which are part of software.

Random factors, mainly arising in the economic processes modeling can be represented in the model as random variables, discrete or continuous, as random events or processes, depending on their nature.

In the following, the notions of the object-oriented modeling concept will be used to describe simulation methods for practical implementation of models for assessing high-tech corporation sustainable development methods. Therefore, we should first outline these notions.

There are six basic notions in the object-oriented modeling concept:

1. The graph of the model. All processes, regardless of the number of structural analysis levels are combined in the form of a directed graph.
2. Transaction. It is a formal request for some kind of service. Transaction, or transact, unlike common queries considered in the analysis of queuing models, has a set of dynamically changing special properties and parameters. The ways of

transactions migration through the stochastic network graph are determined by the functioning logic of the model components in the nodes of the network.

Transact is the dynamic unit of any model running under the simulator.

Transact can execute the following actions:

a. Generating new transaction group;
b. Absorbing other transactions of a specific group;
c. Capturing and leasing the resources with their consequent release;
d. Determining the service time, accumulating information about the path traveled and have information about its own future path and the paths of other transactions.

The basic transaction characteristics are:

a. Unique Transaction Identifier;
b. Transaction Group Identifier;
c. Sets of resources to be kept and used for the time of leasing;
d. The transaction lifetime;
e. Priority. This is a nonnegative number; Priority is taken into account when accessing resources, for example, in a queue;
f. Service parameters for any querier (including probabilistic characteristics).

3. The nodes of the network graph are the transactions (not necessarily queuing) servicing centers. In nodes the transactions can be delayed, serviced, they can generate new transactions and terminate other transactions. From the point of view of computing processes, an independent process is generated in each node. Computations are performed simultaneously, coordinating each other. They are implemented in a single simulation time, single space, taking into account temporal, spatial and financial dynamics.

   Numbering and naming the nodes of the stochastic network is done by the model developer. It should be taken into account that the transaction always belongs to one of the nodes of the graph and, regardless of this, refers to a certain point of space or location, the coordinates of which can change.
4. Event. An event is the fact that one transaction leaves the node. Events always occur at certain points in time. They can be linked to a point in space. The intervals between two neighboring events in the model are, as a rule, random variables. Suppose that an event occurred at time t, and the next closest event shall occur at the time t + d, but not necessarily in the same node. If continuous components are included in the model, then obviously the control can be delegated to such components for only the (t, t + d) time interval.

   The model developer cannot manage events manually (for example, from the program). Therefore, the event management function is given to a special control program, a priori embedded in the model.
5. The resources in the process of modeling can be characterized by three general parameters irrespective of its nature: its capacity, residual balance and scarcity. Capacity of the resource is the maximum number of resource units that can be used for various purposes. Residual balance of the resource is the number of

currently unused units that can be used to satisfy transactions. Resource deficit is the number of units of a resource in the aggregate query of transactions that are in the queue to the resource.

When solving the tasks of dynamic resource management, one can identify the main types: material, information, personnel and money resources.

6. Space: geographical, Cartesian plane.

Notions 2–6 are kinds of objects of the simulated system. They appear in the graph and interact according to certain rules and patterns. Thus, the upper graphic level of the model, consisting of standardized blocks is realized.

To obtain accurate estimates of the economic efficiency of the assessment of competencies at enterprises of a high-tech corporation, it is necessary to use mathematical models that allow us to consider the quantitative and qualitative indicators of these processes using simulation modeling.

The main approaches to the qualitative and quantitative assessment of the economic efficiency of developing new competencies at enterprises of a high-tech corporation using a mathematical model are considered. The proposed schemes for new competencies development allow considering and evaluating various options for the production development in terms of their economic efficacy.

The possibility to obtain estimates of the sustainable development programs economic efficiency at enterprises of high-tech corporations, as well as forecasting of various scenarios of the economic efficiency of these programs will allow developing optimal strategic solutions that would ensure the sustainable development of those enterprises.

The generalized architecture of the information system implementing a simulation model for assessing new competencies is presented. At the heart of the infologic model of the developed architecture are the principles common to OLAP-systems (On-Line Analytical Processing). The general principles of interaction of the information system modules are developed and its main advantages and disadvantages are considered.

General principles for building simulation methods for the practical implementation of models for assessing the sustainable development of high-tech corporations methods are developed. A generalized algorithm for constructing such systems is considered. An overview of the tools that can be used to build simulation models for the practical implementation of high-tech corporations sustainable development assessments is presented.

Chapter 8
Practical Aspects of Competencies Development of High-Tech Companies

8.1 Practical Bases of the Competence Approach in Management

Integration of organizations and enterprises is an instrument of strategic management. Therefore, the task arises of determining the critical factors that, in one way or another, influence decision-making procedures within the process of strategy formation and implementation, as well as its efficiency. Moreover, it becomes necessary to estimate the range of values of those indicators by which the intensity and stability of the relevant factors is determined, that can be expressed by the variance or the standard deviation. The main difficulty lies in the fact that the traditional approach to the study of the certain factors influencing the object of interest to the evaluator that consists in building a multiple regression model faces the obstacle of meaningful multicollinearity and heteroscedasticity. Formalism and quantitative evaluation methods in this situation are possible in very limited limits, and the role of qualitative scales of assessment increases.

The task of forming the nomenclature of critical factors refers to the initial stages of the management process, namely, to the stage of the model specification. There are no universal recommendations for the implementation of this stage. The weight of the evaluator's preferences at this stage is very high. They affect the choice of the theoretical concept, which is the basis of the assessment.

Numerous economic theories are known to sufficiently broaden the list of production factors that are necessary in the conduct of economic activity. Early theories, such as Marxism, singled out labor power, subjects of labor and means of labor as factors, combining them into two groups: the human factors and the material factors of production. Marginalist theory traditionally distinguishes four groups of factors: land, labor, capital, entrepreneurship. In the postindustrial economic theory, the information factor is added in the production factors classification.

From the point of view of its own meaning, the land cannot serve as an integrating factor, if only because the aircraft instrument engineering capacities are distributed

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in different territories, including those located far apart. Industrial, economic and organizational integration does not imply a large-scale movement of fixed assets because of obvious economic meaninglessness.

Entrepreneurship, whatever this term is understood, is an abstract category that, in applied research of economic or managerial content, is difficult to analyze, since it refers more to the socio-psychological paradigm. In addition, the importance of entrepreneurship factor for the studied problem somewhat decreases, since it is advisable to integrate the enterprises and organizations of the industry in the legal form of Public Private Partnership.

Labor resources are a type of resource that is sufficiently independent, and its management efficiency is poorly projected for quite a variety of reasons, including demographic factors, socio-psychological and cultural ones. As it was already mentioned, the theoretical and practical results achieved recently in the field of solving problems of industrial enterprises and organizations integration do not consider the factors related to labor resources to be significant.

The importance of economic factors for integration problems is not questioned. Any economic activity is oriented to economic indicators and is carried out in accordance with the prevailing economic conditions. But these are general considerations. If we consider the importance of economic considerations in solving integration problems, then a rather serious contradiction is easily revealed.

As with any problem related to the formation and implementation of strategic plans, economic factors in economic integration, one way or another, boil down to assessing the financial flows generated by the implementation of the strategic plan. The higher the current value of such a flow, the more attractive is the strategy from the point of view of economic factors. However, such an approach to the formation of the preferences of the decision-maker is fraught with considerable uncertainty, since the members of the income and cost flows in the financial model are poorly assessed by all the parameters describing them.

First of all, the uncertainty associated with the horizon of planning is great. What is more preferable: the high current value of the cash flow corresponding to one or another kind of the integration activities for a short period of the integrated system operation or a smaller value of the same indicator for a longer period? The answer to this question is the prerogative of the subject of integration. Therefore, it is difficult to take into account economic factors in a formal or formalized methodology.

Secondly, the rate of return on capital is variable. Moreover, its value does not depend on the subject of integration.

And, finally, the members of the cash flow generated by this or that variant of integration activities are nothing else than the result of forecasting. As we know, the results of the forecast made in any form, including in the form of a directive forecast cannot cause special trust.

As it was established earlier, the problems of integration are closely connected with the categorical apparatus of production cooperation and specialization. Economic factors influence integration decisions as characteristics of value added chains, but the assessment of such chains is largely determined by the technology used or planned for implementation, so this aspect will be discussed further.

Different approaches to integration and forms of implementation of integration activities can expand the range of significant factors. Thus, vertical integration aims to increase the produced added value by rational distribution of production technologies among the participants in integration.

This factor would have priority, if not for the peculiarities of the current situation in the industry. The vast majority of enterprises in the aircraft instrument industry have incomplete technological cycle; they will be able to produce certain product groups at relatively low costs autonomously, with minimal interaction with other production entities of the industry. There is neither economic nor technical sense in reorienting the enterprises in order to form value added creation chains with their participation. For this reason, such an economic factor as value added, cannot be the goal of integration activities. This, of course, does not exclude the use of the indicator to characterize the performance of the industry.

Horizontal integration is known to give the priority to such a marketing factor as the market share. However, such an approach to integration presupposes a significant reduction in the status of enterprises and organizations of the industry, up to a complete loss of independence, which, of course, is an ill-posed goal and, moreover, is not feasible today.

Thus, economic factors, or capital in terms of economic theory, in the process of making an integration decision should be attributed to a lower level of decision-making; they are opportunistic and, therefore, less significant from the point of view of the integration strategy.

Information factors of integration with some reservations include technology factors that characterize not only production assets and their use, but also information technologies, that is, the means of managing the industry.

Applied production technologies are determined by the peculiarities of the products. The technologies for the production of aggregates can in principle be implemented at enterprises operating outside the cooperative network, although from an economic point of view such an approach to the organization of production is irrational. The other thing is complexes. As you know, a complex is two or more products intended for performing interrelated functions. Taking into account the specifics of the industry's products, it can be supplemented that the complex is a product that includes components of different physical natures. Now it is already difficult, if not impossible to manufacture products of this kind at one enterprise on its own. The production of complexes necessarily involves cooperation. However, the difference in the features of the complex components and the technologies used in their production makes it necessary for the existence of enterprises of a special kind: integrators that would assemble the components and perform their adjustment and tuning.

Almost any enterprise of aircraft instrumentation already performs the functions of an integrator through its assembling and adjustment units. However, due to the increasing complexity of the products, the capabilities of individual units are insufficient. Trends in the technological development of the industry confirming the above provision are summarized in Fig. 8.1.

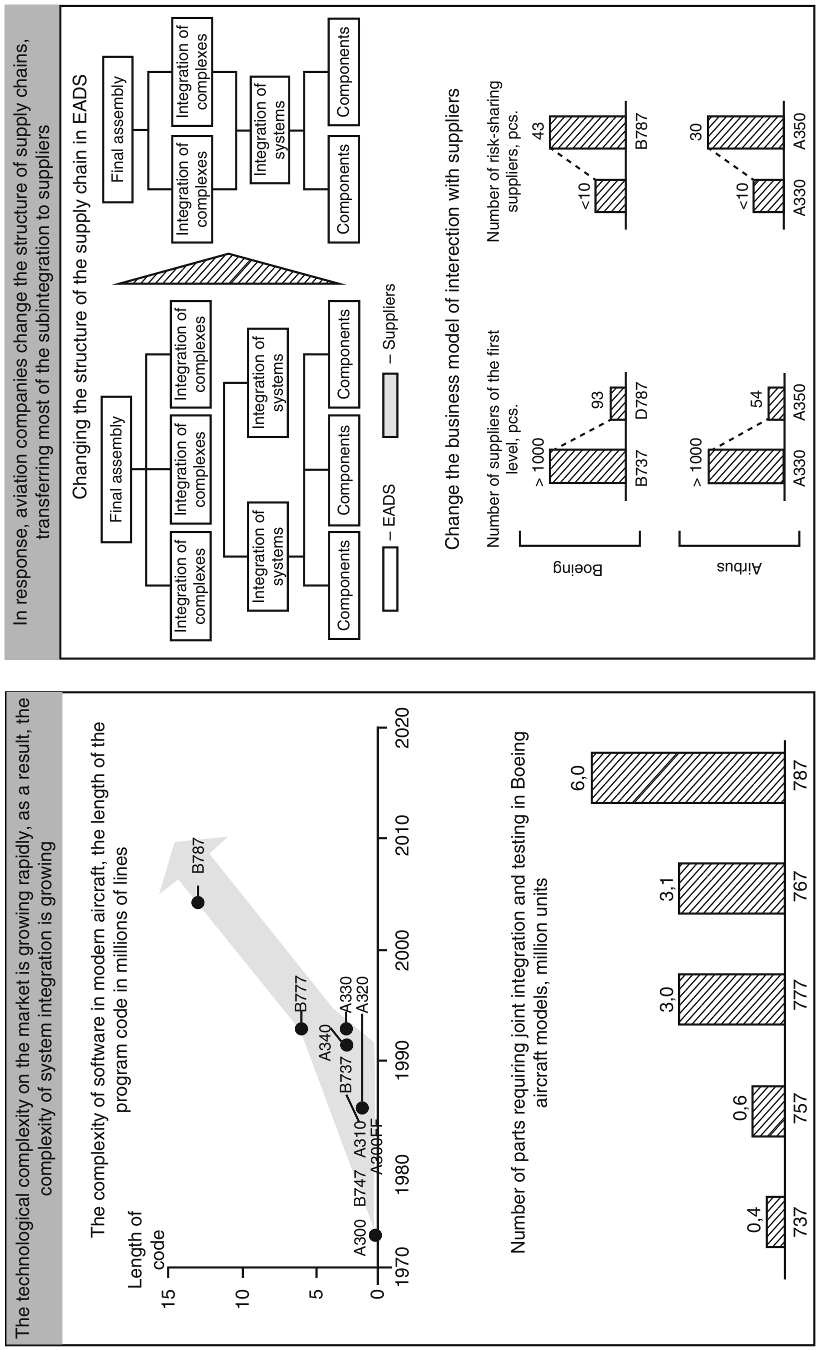

Fig. 8.1 Technological development and the increasing complexity of supply

Earlier it was established that among the competencies of the organization, it would be possible to allocate standard ones. Obviously, these are the competencies associated with the creation of a certain product range, and these are traditional, relatively simple products. These competencies are determined by the features of the products and the production base technological specifics of the enterprise conditioned by these features. As the analysis shows, many companies in the industry have a set of standard competencies.

In connection with the objective necessity of creating production complexes at the enterprises and organizations involved in this process there came out a lot of additional integrating functions that require a certain specialization. Previously, there was no need for such specialization. This specialization and the corresponding methods and means are advisable to be designated as core competencies. Enterprises and organizations that carry out the functions of an integrator and are carriers of core competencies should be attributed to a particular type of business entities, namely, the competencies and innovation management centers. Moreover, the competencies and innovation management centers can serve as integrators both in the production and management sense. It is known that efficient management cannot be implemented without solving financial problems, problems of automated management information processing, and without using methods and means that ensure information compatibility of enterprises and organizations interacting within the industry. Such methods and means include the standardization of the workflow, the quality management system, as well as the particular factors of information technology, such as the platforms, data formats used, etc.

Thus, it can be concluded that the main integration factors are technological factors, both production and information ones; the economic components have a lower priority and can be used as a basis for evaluating various options for integration activities. At the same time, technological factors determine the appearance of brand new subjects of economic activity, the integrators, or the competencies and innovation management centers, which are the basis for the organizational and industrial integration of the industry.

8.2 Practical Experience of Increasing the Competitiveness of High-Tech Companies Based on the Competence and Innovation Management Center

It is generally believed in the West that the main role of the state in the formation of a knowledge-intensive sphere consists not so much in implementing high-tech projects based on state orders, but in stimulating the high-tech organizations development, diversifying their activities, and attracting private investments.

The modern market of innovations is impossible without government regulation. State regulation in the innovation sphere is the purposeful influence on the micro- and macroeconomic processes of the innovation economy development in order to maintain its stability or change in the direction necessary for society. In the modern era of globalization, any closed system focused only on the solution of internal problems, loses to open structures. The success of an organization on the market depends not only on the quality of its products and economic achievements, but also on the image, public recognition. This is why foreign companies are eager to cooperate with government structures, the status of a contractor in a joint project with them would open the way to "big business." In turn, such cooperation gives the state the opportunity to use the mechanisms of outsourcing to reduce its costs, to use competition between suppliers to reduce the prices for components. In any case, the development of such mutually beneficial relations is largely due to the information exchange development and the optimization of the use of the competencies of actual and potential scientific and production activities participants.

The set of tools and the degree of state intervention in the innovation economy are not universal for any country. There are a specificities, differences in the application of certain tools in a given country or group of countries.

Consider the experience of a number of leading countries that have reached a high level of development in science-intensive industries. These are, first of all, Japan, the United States, the EU and rapidly developing China.

The analysis of the Japanese organizations experience makes it possible to distinguish the following features of their competitiveness management strategies:

- The domestic Japanese market remains open only for high-quality products of both domestic and foreign origin. Therefore, competition in the domestic market stimulates the improvement of the quality of products primarily in the domestic market, and only secondly, in the external market;
- The high level of competition in the domestic market stimulates the constant introduction of innovations, and this, in turn, contributes to maintaining a high competitiveness level of Japanese organizations in the world market;
- The high products quality level is supported by the use of an efficient quality management system and highly skilled workers and is conditioned by the involvement of all the organization personnel in the quality management;
- The introduction of information technology into industrial systems and the use of information in the service sector;
- Making changes in the production management processes in the direction of flexibility, increasing attention to quality and cooperation;
- Major investment in new technology and rapid deployment of new products.

The main idea of Japan's state strategy in the field of technical re-equipment of industry and introduction of innovations in the post-war period was to find ways of applying scientific developments and innovative technologies of other countries. The Japanese national innovation system was aimed at imitating and qualitative improvement of products and technologies created abroad.

Currently, the successful development of innovative processes in Japan is largely due to the close cooperation of government organizations and private corporate structures. In general, the state regulation methods applied in Japan in the area of scientific and technological development are standard and do not differ significantly from the methods used in other developed countries.

But it should be noted that there is a number of characteristic features inherent only in the Japanese innovation system:

– The targeted allocation of funds provided by private banks and the directing these investments in priority sectors of the economy;
– Support and assistance to enterprises that purchase advanced foreign technologies;
– Governmental control over scientific and technical exchange with foreign partners.

In 2001 there was a radical reorganization of the government machine in order to improve the efficiency of the government regulation of the scientific and technological area. The Ministry of Economy, Trade and Industry of Japan is the key government body that determines the strategy for the industrial development in Japan and controls industrial R&D development and implementation.

The Cabinet of Ministers of Japan developed a strategic document regulating the country's innovation activities until 2025, "Creation of Innovation and Global Information Dissemination of Information 2025."

As a result of active innovation, Japan is one of the leading countries in the world in terms of GDP per capita, resource efficiency, the rate of economic growth among the industrialized countries, and the life expectancy of the population.

Nevertheless, according to the estimates of the Science Council of Japan, the efficiency of national expenditures on innovative development in the priority areas is about half that in the US and the EU which forces the Japanese government to step up efforts not to lose in the global competitiveness of the country and business.

To accelerate the development of new competencies in the main areas, supportive competencies are developed. For example, in early 2014, Japan established the Technology Research Association for Future Additive Manufacturing for developing industrial 3D printers, designed to manufacture complex parts from metal for aviation and medicine. National universities and 27 technology companies became members of the association, including Panasonic, Mitsubishi Heavy Industries, IHI, Kawasaki Heavy Industries, Komatsu and Nissan Motor.

Since the creation of the Japanese Sharp Corporation in 1912, innovations have become an integral part of corporate philosophy. To date, the company is the largest producer of digital information technologies; it strives not only to increase the volume of trade turnover, but also constantly contributes to the development of culture and the well-being of society through the development of unique innovative technologies. The company considers the continuous creation of innovations as its duty, therefore around the world 8000 researchers work in the offices of the corporation, the company invests about 6.5% of the profit in research and development of new products. Thereby, the course on Open Innovations and the collection of required competencies around the world, including from external sources is taken.

The history of development of own competencies in the largest concerns of Japan can be considered on the example of automobile concerns Subaru, Suzuki, Datsun—

Nissan, which, however, along with cars, produce other products in the field of heavy engineering and instrument making. The biggest advantage of the Japanese automotive industry is economy; it manifests itself in everything: from the production process organization (minimal costs, carefully thought-out stockpiles, recycling all materials, use of robots for basic work) to the cars themselves (design, finishing materials, engine and components).

The experience of Japan shows that at some point the borrowing of technology and the import of high-tech products should be replaced by own developments; for doing so it is necessary to continuously develop own competencies.

The Japanese system, of course, has its own special features, consisting in certain relationships between employees and the company's management. The system of lifelong hiring, high qualification of employees, the system of continuous professional development against the background of very high sensitivity to new knowledge due to the mass involvement of the work collective in creative processes and the perfect technologies for the exchange of experience have made it possible to achieve impressive results.

In this context, the role of the government in ensuring national competitiveness is particularly clear. Within the framework of the Japanese model the construction of technopoles is postulated which would concentrate R&D and science intensive industrial production within a highly centralized model of assets cross-ownership under the ultimate control of government structures and major corporations.

The US, on the contrary, has traditionally been considered an adherent of the free market. Here, financial regulation instruments come first. US federal authorities finance science through the mediation of specialized agencies. However, since 1948, the US has been actively using the mechanism for purchasing innovative products, including from small and young firms, which is an indirect form of government incentives.

US legislation strongly encourages the transfer of R&D results generated by public funding to the private sector. An important role in this process is played by the Federal Laboratory Consortium for Technology Transfer, which includes all major federal laboratories and research centers.

The role of the government in the US goes far beyond direct financing of R&D and consists in determining the national scientific and technological development strategy and in shaping the conditions for the private business to participate in the scientific and technical partnership.

With the collapse of the USSR and the end of the confrontation between the superpowers, the United States turned to a new model of scientific and technical policy as the basic structure of goals and objectives has changed. The disappearance of the "Soviet threat" changed the attitude towards scientific research and canceled the "sanctity" that existed during the Cold War.

By the early 1990s, there was a consensus in American society about the need to activate innovation, and in 1992, the transformation of policies in the field of R&D and innovation and the radical change in the state innovation policy began. A key role in the knowledge economy began shifting from the state to the private sector.

U.S. government agencies have actively encouraging the establishment of research centres and venture capital funds. The U.S. National Science Foundation insists, the most efficient research centers and venture funds during their first 5 years can be fully or partially funded from the federal budget. As a rule, the most promising high-tech research which could bring the greatest economic effect is financed in full because of their complexity, high project implementation costs, risks arising at all stages of the life cycle and the high level of international competition. In the American innovation system there is a practice of pro bono licensing for the commercial use of the intellectual deliverables patented in the course of research conducted at the expense of the federal budget and owned by the government. A feature of the US government policy in the field of innovation is also the low agency-level concentration of decision-making on the innovative projects development and implementation.

State departments and agencies are financing not only private projects, but also implement own research and development. The largest agencies are the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the National Institutes of Health (NIH), and the agencies and departments of the US Department of Defense, such as the Defense Advanced Research Projects Agency (DARPA), the US Air Forces and the Navy.

A special role in the development of innovative research in the US is assigned to the Defense Advanced Research Projects Agency (DARPA) established in 1958 within the US Department of Defense. The purpose of its creation was to ensure the superiority of the US armed forces, to prevent the sudden emergence of new technical means of armed struggle which could be used against the United States, to support breakthrough studies, to bridge the gap between fundamental research and their implementation in the military sphere. Most of the technological innovations that shaped the appearance of the modern US armed forces were developed and implemented with the direct participation of DARPA. These include the stealth technology, various high-precision weapons, the latest means of reconnaissance and surveillance. Although the agency's activities are carried out in the defense sphere, almost all its programs have a dual purpose. The development and further development of the Internet is one such example.

Despite the fact that all US military agencies have their own R&D budgets, DARPA carries out research in those areas of scientific research that cannot be financed within the framework of other agencies' programs. The DARPA budget in fiscal year 2015 was $2.915 billion, the budget for 2016 was approved at $2.973 billion. DARPA is executing about 250 programs within the framework of 2000 contracts, grants and other agreements with corporations, universities, laboratories of the US Department of Defense and other organizations.

The impressive success of DARPA led to the creation of similar structures in other countries: DLR (Germany), MAFAT (Israel), SASTIND (China), DRDO (India), GDA (France).

The main role in the development of aviation R&D among US federal agencies belongs to NASA, the Federal Aviation Administration (FAA) of the Department of Transportation and the Department of Defense. NASA objective in terms of science is to develop new technical solutions for the development of aviation and space exploration.

Improving the connection between military and civilian directions in the science and technology progress contributes to strengthening the connection between different sectors of the economy which is an important factor in the mechanism of using new forms and methods in science and technology progress. In fact, it was precisely this that laid the growing role of innovation.

The convergencing of the military and civilian economy development levels in the US led to industrial modernization, created real conditions for strengthening their interaction, removed technological and many other obstacles to mutual overflow of technologies.

It is quite common to the United States to create expert bases and attract the widest possible circle of specialists to solve problems related to the competencies development and management. An example of modern competencies management is the use of the Internet community members' ideas to create a special product; the use of these ideas will help in more accurately forecasting the demand and, accordingly, estimating the costs by attracting the widest possible group of specialists to this task. When applying these methods, the increase in the accuracy of forecasting sales of new products may increase by 2–3 times.

A successful example of working with universities and research institutes and the use of corporate venturing is the company Intel, which has long been working on the model of Open Innovation in the part of searching for and management of competencies. At Intel, basic research and development is not carried out in their own research centers, but outsourced. If it is not clear what technical solutions should be used, Intel orders a search for such decisions to universities and research institutions. The challenge is to choose one or two of the range of solutions proposed by universities which could be brought to life. It is important to note that the universities and research institutes keep all rights for further development of their inventions. In the same time, Intel reserves the non-exclusive right to use third-party companies; technologies.

The competitive methods of the European Union and Europe as a whole differ from those American ones. Europe actively encourages the development of competition through the creation of small enterprises that are assisted in obtaining long-term and short-term loans, upgrading the skills of management personnel, they are granted tax breaks, commercial information, and legislative guarantees are created to prevent bankruptcy.

The government influences production by means of the state order system in both state and market sectors. Management of state enterprises is carried out on the principles of contracting. The planned contract that is concluded between the State and its enterprises, acts as a form of public sector management. The state order can be considered as a method of interaction with the market sector of the economy.

With regard to the costs of European countries for R&D, the third, fourth and fifth places in the world in terms of absolute costs belong to the UK, Germany and France, investing in the development of science and innovation 2.4%, 2.3% and 2.2% of GDP respectively; financing from the federal budget is from 35% to 45%.

Assistance and stimulation of innovation development of strategic industries in the European Union is carried out at the national and international levels. In order to maintain and improve competitive advantages, to ensure high positions in the world innovative products market, European countries unite the existing potential for enhancing the scientific and technological level of European high-tech corporations.

The main areas of European Union policy in the field of innovative development include:

– Unification of antimonopoly legislation;
– Development and application of a unified accelerated depreciation system of equipment operated by high-tech corporations;
– Support for small high-tech business, including preferential taxation;
– Providing direct financing of high-tech corporations in order to stimulate innovation in the field of new technologies;
– Implementation of cooperation mechanisms for research and educational institutions and organizations that produce high technology products and services.

The basis of the EU innovation policy is the Plan for the Development of the International Infrastructure of Innovation and Technology Transfer (1985). The purpose of this document is to accelerate and simplify the mechanisms for introducing the results of scientific research into the production of finished products at the national and supranational levels, and to stimulate the processes of innovation transfer.

One of the instruments for stimulating and coordinating innovation policy in the EU is the Euro Plus agreement adopted at the initiative of Germany and France in 2011. Concluded by 17 eurozone countries, as well as six non-member countries, it provides for an annual definition of activities aimed at implementing the provisions of the Europe 2020 strategy.

The main principle of the EU supranational institutions activities is the principle of subsidiarity annex, according to which they take part in stimulating innovation activity only when the achievement of specific goals by the participating countries without any support is hampered, and the fulfillment of the tasks set would have a significant socioeconomic effect.

It should be noted that in practice the stimulation of innovation in the EU often goes beyond national borders. The policy of European countries in the field of science and innovation is regulated by Framework Programs (FP). For example, research into the genetic nature of living organisms and the application of the results for further developments aimed at addressing quality improvement and prolongation of human life have become one of the priority areas conducted within FP-6 (2002–2006, budget—17.5 billion euros).

The budget of the Seventh Framework Programme (FP 7) for 2007–2013 amounted to 73 billion euros. The Programme was divided into four specialized sections, corresponding to the main objectives of the European science and innovation policy: “Cooperation”, “Ideas”, “Human Potential” and “Research Potential”. The subprogramme “Cooperation”, among other areas of joint research, included studies aimed at solving priority tasks in the field of transport, including aeronautics, and security and space.

International cooperation within the framework of these European programs assumes that all areas of activity on various research topics are open to scientists and organizations from third countries.

Within the framework of the state procurement scheme in France and Belgium, control over public expenditures at all stages is envisaged (decision making, cost estimates, analysis of the compliance of planned expenditures with budget capacities, approval of expenditure documents, control of payment on contracts). Characteristic for France is the creation of special commissions, selectively checking the correctness of contracting. Each agency and local government form their own procurement unit, whose functions include contracting and monitoring their execution.

Unlike the United States, Europe has not yet formed a coherent system of interaction between the military and civil sectors of the economy, and so far there have been tendencies toward "independence." However, there has also been development of partnerships with private companies. Special mention should be given to Copenhagen Suborbitals, a non-profit organization from Denmark founded in 2008. In 2012 and 2013, SMARAGD and Sapphire rockets were launched respectively. The launch of the first of them was only partially successful: after some time after the start, the electronics failed. But the launch of the second one which was intended for testing flight control systems passed without any problems. The ultimate goal of the company is the development of the Heat-1600 rocket, suitable for suborbital flight.

The second feature of the EU is the link between political and economic factors. In connection with the expansion of the EU, numerous socio-economic problems have arisen in the countries of Western Europe that ultimately led to a restriction of budget financing of innovation, on the one hand, and the emergence of many differences in national legislation, on the other.

The analysis of the mechanisms for the development of competencies is conducted on the example of the largest heavy engineering corporations of Germany and France.

The research center of the Volkswagen concern in cooperation with other automakers in the framework of the INTERSAFE-2 research project under the auspices of the European Commission has developed an innovative system of driver assistance at intersections. The car informs the driver information not only about the visible environment, but also about objects that are outside his field of vision. Thanks to the new competencies centers and the formation of consortia in Volkswagen, the technical characteristics of such a system were improved that led to the successful solution of the problem.

For the first time the concept of BMW unified research centre appeared in the early 1970s. At that time, thousands of company employees were scattered all over Munich, and it was difficult to establish normal working contact between them. Officially the research center is called FIZ, but it is often called the "factory of ideas". It is one of the youngest and most powerful research complexes in Europe.

The French Bostik company is the leading global expert on the market of industrial production, construction and consumer market (including new materials). For more than a century, the company has been developing innovative adhesive solutions that are increasingly adapted to the current needs of the industry. Bostik Technology Center is a world-class Research Center; it seeks to develop core competencies and focuses on developing smart adhesive materials.

The practice of the EU largest corporations shows that the introduction and formation of new core competencies allows achieving new technology levels, as well as improving advantages in comparison with competitors through the creation of new specialized divisions related to risky areas. The basis of the policy are consortia for new competencies creation, and the competencies centers.

Finally, we should briefly discuss the experience of China, where market and administrative mechanisms are connected. The main feature of China is the ability to replicate others' achievements which is unacceptable for European and American sense of justice. According to one of the Chinese economists Hu Angang, in the process of creating the Chinese national innovation system, the most important factor in the transition from an extensive to an intensive model of economic growth is the continuous improve in the technological production level. China took the road of industrialization later than many developed and developing countries of the world that gives it the so-called "advantage of backwardness", which manifests itself, for example, in the broad opportunities to overcome the technical gap from the developed countries through importing their innovative technologies and carrying out own R&D based on these technologies, with minimal time and financial costs.

In general, three major sources of technological innovation can be identified in China:

1. Import of foreign innovative technologies through the organization of foreign trade, including the transfer of copyright and licensing, and the import of high-tech means of production;
2. Acquisition of foreign technology and innovation based on attracting foreign direct investment;
3. Development and introduction of own technological innovations obtained due to the growth of public expenditures for R&D.

For the first time the task of transition to an innovative type of state was set in 2006 with the adoption of The National Medium- and Long-Term Program for Science and Technology Development (2006–2020) (Plan 2006–2020). According to the Chairman of the PRC, "the essence of such a state is that the power of science and technology should contribute to economic and social development and national security, so that the synthesis of basic scientific research and the study of advanced technologies significantly strengthens and allows achieving scientific and technology results that would be essential for the whole world".

The Strategic Plan 2006–2020 should contribute to the creation of a more viable economic growth model based on innovative development.

Summing up the analysis of international experience, as general directions of national policies in the field of improving the competitiveness of high-tech corporations, it is possible to single out:

- Ensuring the availability of financial investment funds;
- Creating a favorable tax environment;
- Technical assistance;
- The formation of industrial clusters;
- Improving regulation in the field of securities;
- Simplification of registration and licensing procedures;
- The creation of intellectual capital in universities;
- The improvement of the education system.

The conducted analysis of corporate competitiveness management in high-tech industries made it possible to identify the most efficient methods for the formation and management of core competencies in the United States, the European Union, Japan and China. From the available data, it can be concluded that different countries apply a variety of mechanisms for the development of competitiveness on the basis of innovations and competencies, the main ones of which are summarized in Table 8.1.

Consider in general the features of the efficient application of the mechanisms listed in Table 8.1.

1. *Involving of the widest possible circle of specialists and experts* is one of the most efficient and widespread mechanisms of competencies management in all the countries examined. One of the effects of this competencies management mechanism is a more accurate forecasting of demand and, accordingly, financial forecasting by involving the widest possible group of specialists to this task.
2. *Establishment of a corporate platform for the exchange and management of competencies.* The most popular platform is InnoCentive (United States), as well as platforms developed in the EU. The efficiency of the platform mechanism for the competencies exchange and management is due to the ability of involving people to generate innovative ideas around the world with minimal financial costs.

   The following main points can be identified as contributing to the efficiency of the mechanism:

   - The project is realized not by one person or certain employees of the company, but by a large group of people independent of each other;
   - Distance work permits access to the services of professionals around the world;
   - Only the final specific product that satisfies the client's interests is important (no nationality, no specific experience in a specific field, it is important that the person has created the best solution for the task);
   - Involving a large number of people allows implementing large-scale projects in the shortest time.

Table 8.1 Competencies management mechanisms by country

Country	The involvement of external experts	Creating a platform for exchanging and managing competencies	Collaboration with Universities and Research Institutes	Corporate venturing	Creation of specialized technological centers	Transfer of business processes to outsourcing
	1	2	3	4	5	6
USA	+	+	+	+	+	+
EU	+	+	+	+	+	+
China	+	+	+			
Japan	+	+	+			

Source: Compiled by the authors

3. Intel (USA), companies of leading European countries in various fields—Bostik (France), Volkswagen and Siemens (Germany), and Hitachi (Japan) demonstrate *cooperation with universities and research institutes in the field of search and introduction of new competencies.* The efficiency of this competencies exchange and management mechanism is due to the use of this type of cooperation as an additional source of innovative solutions and to involve specialists with the necessary competencies.
4. *Corporate venturing.* Corporate venture investments as a tool for improving competitiveness have been used throughout the world for more than 40 years. Corporate venture investments (corporate venturing) are carried out through own corporate venture fund/division or through equity participation in other venture funds. Sometimes a fund is not created, and its tasks are performed by the company's internal divisions. Such investments are an efficient tool of competition. Corporate venture is characterized by compliance with the basic laws of the venture industry. Corporate funds and units to find ideas and developments of interest to their business interact with leading universities and research centers. Despite the fact that such investments are associated with high risks, it is likely that some portfolio companies will subsequently grow into large ones, and one or two of them will bring truly breakthrough innovations that will make the parent corporation more competitive. For example, Cisco (USA), being a small company, managed to oust Lucent Technologies from the market by purchasing new technologies and investing in promising technological start-ups. Intel (USA) also makes a decisive bet on the use of venture capital that allows supporting promising market projects. One of the biggest corporate venture funds in the world is Intel Capital. In the portfolio of the fund are not only companies working in the field of computer technology and semiconductors. Motivation for the company's adoption into the portfolio can be the promotion of Intel solutions within the framework of funding technological start-ups, as well as the integration of technologies into Intel's business itself.
5. *The efficiency of the Competencies and Innovation Management Center* as a mechanism for competencies exchange and management has been confirmed in

practice by many foreign leading corporations and is due to the fact that with the help of the Competencies and Innovation Management Center, the corporation can monitor the most important areas of activity by collecting relevant competencies and finding ways to use them as efficiently as possible.

In general, the efficient work of the Competencies and Innovation Management Center allows the following functions:

– Analysis of the current state of competencies management in the organization and provision of relevant materials from which users will be able to learn where to obtain the necessary competencies and knowledge, and management will be able to draw conclusions about the effectiveness of a direction;
– Identification, formalization and proliferation of implicit competencies of the organization;
– Collection and description of competencies that were acquired and developed as a result of specific projects;
– Management of the competencies bases of the organization: their maintenance, updating, integration, creation of convenient search mechanisms;
– Ensuring communications between users and experts who possess the necessary competencies;
– Protection of intellectual property of the company;
– Training new employees, development of competencies, transfer of experience.

6. *Transfer of business processes to outsourcing*. At present, in science-intensive industries there is a tendency to outsource not only the simplest business processes, but also the processes of complex assembly and design. The strategy of developing its own design competencies, provided that production processes are completely outsourced, is typical for German BMW Company. The practice of the largest German heavy machinery companies shows that the transfer of non-core competencies to outsourcing and targeted development of core competencies allow achieving new levels and also improving their advantages in comparison with competitors. This task is already closely recognized by many high-tech corporations, but it is necessary to strengthen the system and turn outsourcing into a clearly structured business process. A criteria basis for outsourcing non-core competencies should be developed based on their comprehensive and systemic review, including taking into account the professional competencies of the staff in four key parameters: strategic importance, risk, cost, quality.

Thus, the analyzed competencies management mechanisms to improve competitiveness, including the use of modern information and communication technologies integrated within a single corporate platform, can become a unique and universal tool and method for finding managerial and innovative solutions, developing the innovative climate of high-tech companies, exchange of technologies and attraction of core competences from the market in order to improve the overall competitiveness of companies.

In order for companies to occupy leading positions in the world market, apart from their own developments and technologies, it is necessary to increasingly involve and implement external ideas.

The use of competencies management mechanisms that have proven efficacy in practice will be efficient if a convenient environment for communication, exchange and management of competencies is organized for the innovation community.

8.3 Application of the Open Innovation Mechanism in Corporate Practice

The Dilemma of Searching and Developing Innovative Directions: "Inside or Outside"

In modern economic conditions, innovations are the key factor of economic growth and the efficiency of organizations development. Innovation consists in the regular generating of new ideas, proposals, inventions, in accelerating the market implementation of innovations, in finding new forms of management, in supporting creativity and initiative.

Adopting the innovative way of development gives rise to many difficulties that managers of companies will face. The first such difficulty is the search for innovative ideas for their further elaborating and transforming them into innovation. According to many consulting companies, the implementation of one innovation on average requires 60–80 different ideas to be assessed and selected.

According to the ideology of Peter Drucker, a prominent American specialist in the field of modern management, there are at least seven sources of innovative opportunities:

- The unexpected event—an unexpected success, an unexpected failure or an unexpected outside event;
- The incongruity between perceived and actual reality;
- Process need;
- Sudden changes in the structure of industry or market;
- Demographic changes;
- Changes in perceptions, attitudes and value settings;
- New knowledge (scientific and nonscientific).

This approach to determining sources of innovation was further developed by other authors who identified internal and external sources of innovation on its basis. The composition of the sources of innovation is shown in Fig. 8.2.

The sources of the organization's internal environment are:

- Changes in the internal environment of the organization;
- Solving problems and eliminating the shortcomings of the organization.

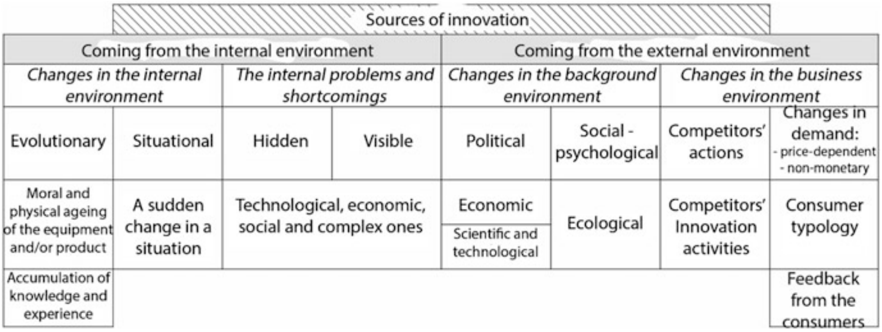

Fig. 8.2 Sources of innovation

Changes in the organization's internal environment provide an opportunity to initiate an innovation process. At the same time, changes in the internal environment of the organization can be evolutionary, or natural, and situational, i.e. the emergence of new situations, some of which can be predicted in advance and used for innovation.

Solving problems and eliminating the shortcomings of the organization is another internal source of innovation. The creative solution of problems allows overcoming existing barriers and stereotypes, and finding new approaches. The problems of the organization can be visible (explicit) and invisible (hidden). Visible problems include problems that interfere with the work of the organization and violate its rhythmic continuous process. Visible problems can be technical, economic, social or complex. A hidden problem is some invisible and therefore unused opportunity to improve something, to introduce novelty.

The sources of the organization's external environment are:

– Changes in the background environment of the organization;
– Changes in the business environment.

By changing the background environment of the organization is understood the change of political, economic, social, environmental, legal, and scientific and technological factors, the latter of which are of greatest interest from the point of view of innovative management. It is important to understand that it is also necessary to analyze the achievements of science in related industries, and even those far from the sphere of the company's activity, since the discoveries made there may later spread into many production and non-production branches.

When searching for innovative opportunities in a business environment, it is necessary to monitor the innovation of the company's business partners, suppliers of materials or equipment; these innovations, through a chain reaction, can launch an innovation process within the company itself. The activity of competitors in the field of innovations is an important direction in the search for innovation opportunities for the organization.

One of the main sources of innovative ideas are the consumers of the company's production. This source can be used in three ways:

- Monitoring changes in consumer needs and identifying hidden needs. Changes in the consumer needs can be a result of changes in perception, values, fashion. Analysis of hidden needs allows developers modifying the product by adding new properties or changing the product's quantitative characteristics.
- Consumer typology. The identification of consumer groups for some specific characteristics, as well as a thorough analysis of special user preferences in each group will provide information on how to modify the base product and create a product line that would have certain distinctive properties. As practice shows, the result of using the information obtained there arise creative design decisions.
- Feedback from consumers. Consumers can generate new ideas due to their experience of using the product and offer product improvement options.

Over the course of a century, companies collected the best scientific and technical personnel from the market for launching a full R&D cycle, from basic research to applied development. The whole path from idea to product was made within the walls of one corporation. The best working conditions were created for the best professionals; insurance, privileges for families, annual bonuses and good pensions were provided. In response, the companies were expecting the utter devotion and complete secrecy from their employees for all the development results to be kept in secret from competitors.

Research work, scientific and applied developments are very expensive, and they are a significant part of the production self-cost. The need to attract more and more new professionals served to widen and consolidate business as only large and prosperous companies could afford a serious R&D. But soon the companies began to realize that their huge technological leaders R&D budgets ceased to protect them from the ambitious newcomers who, without having comparable resources and personnel, snatched a good big market share from them.

The top-management logic of the most companies of the last century was looking like that: All the best specialists work with us. This means anything done without them is anyway worse. For the same reason all the the company's inventions were patented and hid from the outside world. This is a vivid illustration of the "Closed innovation." The problem with this model is that large companies often cannot properly manage the results of their own developments. The technologies which are the base to build global businesses, sometimes seem hopeless, because they go beyond the competence of companies. Sometimes, so that commercial development potential is revealed, the company should combine it with technologies available to players from neighboring industries.

Since the product lifetime in the market is limited, the speed of bringing new products to the market is crucial. In these conditions, small mobile technology companies have the advantage over the laboratories of large corporations. Science and technology professionals are also more mobile because they use the support of venture capital and realize their potential within startups, not large corporations.

Also, the expansion of information horizons allowed the graduates becoming all so points. Thus, now not only the employer is looking for the best employees (although this is certainly true), but also the graduates are picking up the best employers of a few dozen worldwide, sometimes throughout life. Retirement from the first job is the outdated logic of the last century. Young professionals are easily accustomed to changing companies, seeking to gain more experience in a variety of industries in different companies. A long list of jobs in the resume is not anymore something negative in Curriculum Vitae. Knowledge and skills are now widespread and dispersed. Only a few of private companies in our time can claim to have the best experts; and those companies are forced to spend on these specialists the lion's share of their profits.

Top management of large companies recognizes that most intelligent and knowledgeable professionals work for someone else. This unpleasant revelation came simultaneously with the intensification of global competition, a change in the speed of innovation and the formation of new fast-growing markets.

The world of modern business has transformed into a horizontal plane. Everybody has become acquainted with each other and now together (or in parallel) are working to solve similar problems. In order to be advised, what is happening around, companies have to share and discuss their own achievements with their colleagues, and even their competitors. These are the theses of the idea and the principles of the Open Innovation model according to which it is impossible to be successful, prosperous and independent... alone. Knowledge, skills, innovation and professionals are scattered throughout the world The Real Professionals are often dispersed through many technological "no-name brands" and start-ups. In order for the company to become successful in the creation and commercialization of innovations, it is necessary to know and be able to use these global resources, professional skills, encyclopedic knowledge, and be a functional part of this relatively open community and a new process.

Corporate science may not have a sufficient level of knowledge to cover all aspects of: it will be trying to solve the problem linearly, despite the fact that there are many bypasses, since the main achievements in science are made as a result of the intersection of technologies.

In formulating and solving the tasks, new, unfamiliar business conditions require more knowledge, contacts outside the neighborhood and known experts, and more of group psychology. The ability to think outside the box, the ability to share the openings and problems with colleagues and competitors, is nowadays a standard set of requirements for new positions in large companies, such as "innovative managers" and the position of "director of innovation." The tasks of those professionals are to look beyond the company in order not to miss innovations and market trends, to distribute tasks and manage large spaced teams, some of which are not subordinated to them organizationally and sometimes completely outside the jurisdiction of their state.

Today, not every business can create such systems, so innovations are passing by. But even if the management of the company is trying to build an open ecosystem around itself, the problem is that in most companies same people are occupying same positions, with outdated logic and outdated thinking, i.e. new roles and tasks are put before the old people. This is the one of the key problems of the company's full transition to the open innovation model, which is that people who are entrusted to implement the new approach cannot, and sometimes do not want to abandon the old way of doing business.

Another set of problems is related to the fact that the desire to work on The Open Innovation model alone is not enough, the same as it is not enough if to want to work with other companies and specialists: it is necessary to achieve that they also want to work with your company Nothing can be done in one company in the world of Open Innovation.

Diagnostics of competencies and decision-making on their development should be carried out in a corporation iteratively (once a year, or once a quarter.) The procedure should be based on the developed corporate regulations and include the following:

– Classifying the competencies as "internal" and "external", "proprietary" and "acquired" (when a recent acquisition);
– Search for new applications of internal corporation competencies in foreign markets using the latest market research methods (forsighting, benchmarking, consumer development, accounting in global markets);
– Allocation of priority competencies for further development: the "core" and the "internal" ones;
– Initiation of the acquisition of competencies not natural to the company which should become "internal" (first of all, "core") competencies.;
– Taking steps to further integrating the competencies that were acquired recently (for example, additional training for employees) into the company;
– Measures to further protect the "core" internal developed and newly acquired competencies—patent protection, hiring and retraining of professionals;
– Creating a list of external competencies for selecting the best outsourcers (and developing the criteria base for such selection).

Open Innovation Mechanisms Implementation

The Open Innovation concept implies the revision of the internal corporate innovation management processes and directing them towards openness, the diffusion of technologies through the consolidating the efforts of universities, national laboratories, start-ups, suppliers, consumers, industry consortia. The Open Innovation concept was developed as a result of the analysis of the best management experience of large international companies, such as Xerox, Intel, IBM, Lucent.

For the first time, the term Open Innovation was used by Professor Henry Chesbrough of the University of California. This model assumes that the company developing new technologies and products counts not only on its own internal corporate R&D, but also actively attracts innovations and competencies from the outside. An increasing share of innovation is not born in corporate laboratories, but is taken in one way or another from the market.

The ineffectiveness of the former model, Henry Chesbrough, explains the new business environment. A product lifetime is getting shorter. So, the speed of introducing new products to the market plays a decisive role. Because of this, small mobile technology companies have the advantage over the laboratories of large corporations.

The Open Innovation model within the framework of a large company implies "the construction of a two-way road, along which perspective technologies from outside developers come inside, and the results of corporate R&D are realized outside that for some reason are not in demand by the corporation itself."

According to this model, not all talented people work in the company. The company should itself be looking for talents outside its borders and establish interaction with them. It is important to understand that external R&D can create much more value than the internal R&D which contribute to only a certain part in the overall value. Intracorporate research is not a guarantee of obtaining profit from them. Building a better business model is more important to market first. The maximum use of internal and external ideas will ensure the company a victory. It is necessary to make profit by giving other organizations the opportunity to use the intellectual property of your company. Company should buy intellectual property from outside organizations when it effectively fits into the applied business model. The Open Innovation model activities are reflected in the form of searching for technologies, ideas, solutions which can help to solve existing problems and meet the needs of customers. There are many technologies and inventions around; it is not necessary to invent, it is enough to license and use technologies that are used in other countries and other industries. The main factor in implementing the Open Innovation model is the cooperation. It is necessary to establish mutually beneficial relations with a large number of people and companies, it is important to select reliable partners who would be able to evaluate the idea, develop it and bring it to the market.

One of the characteristic tools of this model are corporate venture funds, which began to appear massively about 30 years ago. Corporate venture funds are distinguished by a strong expert and technological base of the parent corporation; this base in turn can be used by invested start-ups. Corporate business incubators (for example, in Philips and Sony) and spin-off funds that allow "budding" technological projects in the form of "outside" companies, together form a balanced system that makes it possible to "grow" innovation.

Frequently attracted external innovators do not need any serious material motivation. The company only needs to debug a clear ideas management that would let to get together, to discuss and analyze the flow of proposals, and show your interest. The value of the Open Innovation model is that it enables one to synchronize efforts on the internal and external R&D and make the R&D costs more efficient.

Intel is the most striking example of using the Open Innovation mechanisms. This company has been working for a long time on the Open Innovation model, while its main R&D is not carried out in its own research centers, but is outsourced. The corporation has an understanding that in order to plan work, you need to look for 5–7 years ahead, in advance to assume the use of certain technical solutions. If it is not clear which ones, Intel starts the search for solutions among universities and institutes, and there can be several such solutions (that is, at the stage of search, there are the diversification and the selection of the best). The task of the developers of the company within the Open Project is to select from the range of solutions proposed by the universities one or two that can be virtually implemented. It should be noted that all rights are reserved by the Universities and/or Research Institutes. In the same time, Intel reserves the non-exclusive right to use third-party companies technologies on its own.

Intel makes high stakes on venture investment for to support promising projects from the market. One of the biggest corporate venture funds in the world is Intel Capital. The portfolio of this fund includes not only hardware and semiconductors companies, but also other IT's. The motif for Intel to add some start-ups to the portfolio can be the promotion of the corporate decisions within the framework of funding those start-ups, as well as the integration of technologies into Intel's business itself.

As another example of a company that has also embarked on the path of Open Innovation, one can cite International Business Machines Corporation (IBM). IBM core competencies were building computing machines and systems. But over time IBM's monopoly position in this market began to weaken, the corporation began to be influenced by factors that destroy the model of "closed" innovation, large consumers began to abandon the use of System 360 and began to prefer less functional but cheaper systems. New market players and the increased supply of venture capital blurred the "closed" innovation IT industry model. This increased the mobility of IBM research staff, employees began to move to work in other companies. As a result, by 1992, IBM's share of the PC market was lower than that of competitors in total. The need for change was evident.

The company has taken a step from the full cycle model to the model of participation in the development of complex systems together with other players. By 1997, IBM had been offering a large number of PC components to other models (Apple Computer, etc.) in the open market, and also worked on complex integrated IT—consulting projects with third parties, whereas ever being the leading developer.

An example of an open policy regarding R&D for the creation of intellectual property can be the practice of Siemens. Siemens partners in the field of innovation are mostly the research institutes, universities (talking not only about research, but hiring promising personnel as well), and developer companies, all together united in a network. For example, Siemens cooperates with the Russian Academy of Sciences, Budker Institute of Nuclear Physics (a member-body of the Academy), Moscow State University, St. Petersburg Polytechnic University.

The most important thing is the mechanism of intellectual property protection when creating joint ventures initiated by Siemens. Patenting and licensing with further rights transfer in an accredited joint venture that is to become the rightsholder. Finally, an important component is honest and open relationships with partners. Siemens is ever open when talking about inventions belonging to the entities that are funding these inventions themselves and keep their rights in joint ownership together with subcontractors who are involved in the creation and development of these innovations. The only exclusion here is the non-exclusive, but free

Siemens' rights possession in those inventions further development. The policy of Siemens in this area is that it is better to share innovations with partners rather than keep them in secret and use the rights to R&D solely.

Cisco is a bright example of the external (spin-in) and internal entrepreneurship strategy simultaneous implementation. Within the framework of the spin-in strategy, Cisco acquires a technology company engaged in a particular activity synergistic with some Cisco's business line. The company is bought at its early stage of development for creation of a new core competence.

Investments in the spin-in company are made on special terms where certain performance targets are denoted. If successful, Cisco buys the company when the latter reaches the target revenue level and forms a client base. At the same time, Cisco controls and participates in spin-in management of the company at the growth stage. Cisco enters its best specialists in the staff of the start-up company, who are monitoring and guiding the corporate growth. After a small innovative company becomes an independent division of Cisco, the problem arises of transferring leading specialists of the parent company to this spin-in, but these specialists are not ever ready to take increased risks. To resolve this problem, specialists are paid large incentive pay.

To implement its own innovative ideas, Cisco has established the Emerging Technology Group (ETG), a subdivision with the status of somewhat like a business incubator, where innovation is turning into new business opportunities, in addition to designing scientific projects and creating patents. The goal of ETG is the market search for new revolutionary ideas and developing such ideas on its own. Before implementing the new idea to the level of a product, department engineers meet with at least 30 potential consumers of Cisco products; anyway Cisco does not have doubts about retaining commercial secrets. Such activities help clarify the specification of the required solution and in the future focus directly on the tasks that need to be addressed in order to meet the needs of consumers.

The largest electronics manufacturer in Europe, the Philips Group, sees its most important feature of the Open Innovation model approach in business cooperation with academia.

The interested companies are given the opportunity to participate in joint projects with Philips at its research center, The Philips High Tech Campus.

Representations of such technology leaders as IBM, Atos Origin, Philips Semiconductors, Cytocentrics are residents of the Campus that also includes up to about 70 high-tech companies operating in adjacent branches. In the Campus, Philips also acts as a technology incubator, providing funding, facilities, business planning and partnerships for startups. The company also assists in licensing the R&D rights in the name of the resident, since its strategy is aimed more at finding technology than on registering intellectual property rights as a protective mechanism. As a result, Philips gets the first access right to a huge number of ideas generated by the numerous campus residents. Moreover, the cooperation of residents and the Philips R&D workers is encouraged. In turn, such projects, if successful, increase the spread of Philips technology. At the same time, offering some self-owned technologies to young companies under its wing, Philips gets the opportunity to sell them a variety of related products and services for technical support. The Single Window Service is one of the Open Innovation mechanisms by the Russian Rostec Corp., whose activities are aimed at collecting and examining the innovative projects and proposals for their possible joint implementation with the holding companies and organizations of the Corporation.

The analysis of world experience shows that the diverse Open Innovation mechanisms can be an efficient tool for technological renewal of a company and a way to generate new revenues.

To implement the mechanism of open innovation, it is necessary to apply a balanced and differentiated approach to regulating innovative development in the context of the world tendencies.

The Open Innovations tools in the modern economy are:

- Technology insourcing, i.e. attraction of technologies with the purpose of development of internal innovative capacities;
- Technologies outsourcing, i.e. transfer of the technologies developed within the organization, for the purpose of developing the market and using designs in the outer world;
- Business models that determine the products and services to be created by the innovative company;
- Efficient interaction between science, education and the production sector on the basis of public-private partnership.

To date, the most gainful strategy is the Open Innovation concept accompanied by an appropriate business model. Companies that close on the internal environment do not have competitive advantages in the market. As a rule, this leads to waste of resources, duplication of already created innovations or third parties research. Companies that are trying to hide information about their research are losing a large part of their potential profits that could have been obtained if only they would had shared a part of their R&D achievements with third companies. All this can lead to the loss of developers and new ideas.

A modern technological corporation should apply the following Open Innovation mechanisms:

- Building partnerships and alliances, open platforms for technology development;
- Organization of cooperation with universities and research centres;
- Establishment of autonomous companies based at universities;
- Building a competitive team, with attracting third-party developers;
- Concluding subcontracts and outsourcing contracts;
- Ensuring the participation of external experts in foresighting activities.

The Corporate Open Innovation Ecosystem

For the effective functioning of an Open Innovation model, partnerships for joint R&D, outsourcing mechanisms, a system for collecting ideas and projects, creating selling and licensing mechanisms, the R&D results are necessary for the Corporate venture investments (corporate venturing) are carried out through own corporate venture fund/division or through equity participation in other venture funds. Sometimes a fund is not created, and its tasks are performed by the company's internal divisions. Such investments are an efficient tool of competition.

Corporate venturing lives mostly on common laws of the venture industry. Corporate funds and units are working with leading universities and research centers: they are looking for ideas which are of interest for their business. Such investments are associated with high risks, but there are chances that by some time through some of the portfolio companies grow into large ones, and one or two of them could make a real breakthrough innovation that would contribute to the parent corporation's competitiveness.

Corporate venture investments as a tool for improving competitiveness have been used throughout the world for more than 40 years.

Investing in start-ups, companies can pursue different goals, ranging from seeking new products and developments for their subsequent use within the company, or creating some subdivisions, and ending with the promotion of corporate own standards, or by generating revenue through the sale of shares in project companies.

Depending on the goals and depth of the corporation's interaction with the startup, the following types of corporate venture investment strategies can be distinguished:

(a) Driving investments: when the strategic goals are prevailing over the financial ones, there is a direct link between the start-up business and the investing company;
(b) Complementary investments: when it is assumed that the startup business will stimulate the consumption of the main products and services of the investing company;
(c) Open-up of new opportunities for investment in projects that are in a trend, but are not the core competencies; Thus, the corporation is "insured" from the risk of market situation change;
(d) Passive investments: a classic venture, when a corporation acts like a common venture fund and expects only to profit from the sale of its shares in the start-ups.

Establishing corporate venture funds stimulates the core competencies and skills improvement of a company managers in the issues of corporate venture investments, as well as the formation of an expert community, those specialized in the field of corporate venture investments.

Chapter 9
Conclusion

The Monograph draws on the theoretical and practical aspects of the highly efficient management of the corporation's competencies leading to the improvement of its competitiveness in the global market. The conceptual apparatus and methodological foundations for improving the competitiveness of the products of the corporation and the industry on the basis of competencies management mechanisms are presented.

In this monograph, the authors come to the conclusion that there is no methodology for managing complex integrated structures in high-tech branches based on core competencies available in various fields.

The monograph presents exactly the methodology based on the set of tools for a holistic system of competitiveness management taking into account core competencies at various levels of management. This methodology is a new step in the development of competencies-based management theory that enables business representatives to determine the directions for developing competencies and improving competitiveness of their companies.

The methodology is based on the original fundamental law formulated by the authors on the interconnection of competencies and the emergence of new markets, described using a mathematical model; the application of the model allows the company identifying new pivot points for economic growth and strengthening its competitive positions in the world.

On the basis of practically tested theoretical developments, the way the competencies which are shaping the human capital of the company affect the competitiveness is determined; practical recommendations on the optimal allocation of the necessary intellectual, material and financial resources for all directions of the company's activities that will be of interest for both state owned and private organizations are given.

Particular attention is paid to researching the management processes of the organization's intellectual resources (competencies) and a competencies management model was formed that allows accumulating information on the corporate innovative and competency potentials at a large high-tech corporation.

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The tools of the proposed methodology are the multicriterial methods of ranking the of the Centers for the transfer of innovation and competencies and the use of human potential developed by the authors, as well as the core competencies quantifying and ranking methodology.

The application of the proposed methodological tools will enable the management of companies to achieve the strategic goals of the organization and implement priority directions of innovation development that contribute to improving the competitiveness of products and the organization as a whole.

To formalize the dependence of competitiveness on the development of core competencies, generalized dynamic models were constructed, the application of which in the complex system of competitiveness management would allow making estimates of competitiveness and determining the competencies which would create the most popular products and services.

At the same time, the Monograph presents the mechanism for creating a corporate network of centers for the innovations and competencies transfer that provides for the exchange of knowledge and technology between companies and will allow them making joint efforts to achieve specific innovative goals which in turn can become a breakthrough in the market of innovative solutions.

The authors formulate pricing mechanisms for the innovative products, taking into account core competencies that allows executives calculating and justifying optimum contract prices for science-intensive products that ensures the high-tech enterprises sustainable development.

In the face of various crises, when solving the problem of economic stability and planning to overstep to the advanced level of development, companies are invited to use the authors' integrated method of expanding production directions; it includes new products creation management which will allow the company's management for considering various options for product lines expansion and evaluating them in terms of their economic efficiency.

The possibility of estimating the economic efficiency, as well as writing various scenarios for new products in doubtful market conditions will allow developing optimal strategic solutions to ensure the sustainable development of enterprises of a high-tech corporation.

The success of the unique competencies application is largely dependent on the development of information exchange and the optimization of the use of competencies of real and potential participants in scientific and production activities. The authors of the Monograph suggest tools for effective information exchange which will lead to a sharp increase in competitiveness, the development of the innovation climate in high-tech companies, the technologies exchange and attraction of core competencies from the market.

The theoretical and practical foundations of competencies management offered in this Monograph as a basis for improving the competitiveness and creating an innovative product being in demand on the market, with the use of modern mathematical and simulation methods, allow writing scenarios and forecasts of a company's sustainability and justifying strategic management decisions during the crisis and post-crisis periods, and developing the competencies management theory taking into account the contemporary socio-economic challenges.

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