Engineering Economy - the Path to Entrepreneurship in Engineering

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The article describes the approaches to the development of entrepreneurship in engineering based on high technologies. It highlights the need to found engineering (engineering and economics centers) as the subjects of the modernization of engineering education and the gradual transition to innovative entrepreneurship in the technological modernization of the country. The article presents some methods of technological marketing as tools to create market-based approaches in engineering and improve regional innovation policies.

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INTRODUCTION

The meeting of the Commission for Modernization and Technological Development of the Russian economy on March 30, 2011 resulted in the list of orders of the President of Russia that included several provisions on the improvement of engineering education. In this article one can find a case study on engineering and economics education in the high-tech field which shows that the organizational forms may be different, but the content changes should be aimed at a comprehensive review of the engineering problems in general: each business initiative has two aspects - technical and economic. Therefore, the development of entrepreneurship in engineering is impossible without improving the human capital. And one of the tools can prove to be education in the field of engineering and economics, if it is raised to a new level - development of engineering centers where training, research and consulting services form an integrated educational complex. Such complex should include educational programs, graduate and degree-seeking, entry into a single network space of engineering and economic services through the teaching teams, focused on the outcome.

ECONOMIC KNOWLEDGE AND MARKET REALITIES OF TODAY'S GLOBALIZED MARKETSHA

In engineering economics knowledge management is a methodology aimed at improving competitiveness and security level of companies and other economic entities in the real sector through the use of a full set of instruments of protection, management and economics of intangible assets, use of human and other resources of a particular company. The engineering knowledge management system develops strategies aimed at providing the necessary knowledge just in time to those members of economic community (companies, structural units of economic entities, subdivision of corporations, etc.) who need this knowledge in order to improve the performance of this community. Since the beginning of this century engineering knowledge

management system has been included in separate university courses that are read at Management Departments of leading universities. There are examples of application of this methodology for the development of engineering education by establishing a knowledge management system for large international organizations, such as the International Atomic Energy Agency (IAEA), the United Nations.

In the domain of engineering knowledge management there has developed a specific terminology, which should be adapted to the economic realities of the industry. It is quite difficult to make in general, so the attempt will be realized only on the example of the engineering problems in the energy sector, particularly in the field of nuclear energy / 1 /. Explicit knowledge includes all those areas of engineering knowledge that can be represented, we can save them, share with other or insert into a database (e.g. a description of the design, composition formulation of a particular material). The implicit engineering knowledge contains different know-how, secrets of excellence, experience, insight and intuition. Communities of practice in many engineering organizations could be considered as the most important, key component of knowledge management: it is a group of practitioners who are allied with a common interest in a particular area of expertise and seek to share with each other their experiences, for example, designers of specific technical and economic objects. Category of knowledge workers has the following main characteristics: a high level of mobility and ability to work virtually, a high level of education, a full set of skills required for the transformation of knowledge, etc.

Competencies of employees' mean abilities working for a particular organization. A spiral of knowledge is the model proposed by Ikudzhio Nonaka / 2 / to explain how the implicit and explicit knowledge interact in an organization to create (generate new) knowledge due to four processes of their transformation, or ways of behavior: socialization (implicit knowledge is converted into implicit), exteriorization (implicit into explicit), combination (explicit into explicit as well) and internalization (explicit into implicit). Engineering education has been developed within learning organizations (universities, engineering centers, specific corporations, etc.).The term learning organizations covers such organizations that as a part of everyday activity create, acquire, transfer and retain knowledge. It is flexible and changes adaptively in response to new knowledge and context of the situation. These are organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning to learn together. In modern Russia national research universities are classified as learning organizations.

Learning community is an informal group of people, without reference to the organizational structure, discussing together those best practices, various issues and skills that the team strives to acquire. And there are many other terminological features / 3,4 /. To extract more value from intellectual capital and engineering expertise organizations need to manage the flow of knowledge between different types of relationships - social capital, internal and external structure. There are three reasons for the need to develop engineering knowledge management systems:

- - Social: in most structures of the real sector of the economy material production becomes secondary compared to the intangible (information, knowledge, experience, etc.) in the conquest, retention and use of appropriate market segments;
- - Economic: The recent economic evaluation (study) of the implementation of any information systems shows that when counting economic return knowledge is taken into account as an economic factor, an information technology by itself is not profitable, profit is generated through transactions with the knowledge (data);

- Technological: the evolutionary process of creating and using engineering knowledge and information technologies follows the vector of "Computing - Communication - Support for mental activity."

ENGINEERING-ECONOMIC OR ENGINEERING CENTERS AS HOLDERS OF INTELLECTUAL CAPITAL

The structure of intellectual capital in any field of engineering or scientific and industrial activity is conventionally divided into three blocks: human capital, organizational capital, customer capital (Figure 1). Personnel (human capital) involved in the domestic industry had been developed and educated for decades, but in the 90s of the last century the tradition of supporting engineering staff was broken and a "human failure" has formed. Today the main task is to educate and consolidate the youth. With the establishment of several public corporations (Rosatom, Russian Technologies, etc.) organizational capital was significantly strengthened. Nowadays this kind of capitals is being structured and developed. This article is mainly devoted to the third component - the consumer capital on the example of entrepreneurship in engineering.

The current stage of development of the real sector of the economy is characterized by competition in the completely new - both qualitatively and geographically - segments of the market in the context of globalization. With the advanced engineering developments (in-situ leaching technology and others), the Russian uranium production in 2010 compared with the previous period has increased by almost a quarter, 17% of the global nuclear fuel market is supplied by Russian gas. Russian manufacturers hold leading positions and a significant part in the world market of enriched uranium product thanks to good engineering practices in the field of a gas centrifuge uranium enrichment. Saving of market segments, improving the economic performance of mining, processing and mechanical engineering enterprises that are engaged in mining, processing and carrying to the commodity form of nuclear energy (nuclear fuel for a specific nuclear power), require development of the engineering knowledge management system. The transition from the network management in complex economic systems to the knowledge management can serve as a method of finding new business models is much more effective engineering and manufacturing activities in the post-crisis Russian economy. Organizational forms of engineering knowledge management can be engineering centers (as stated in the list of orders of the President of Russia accepted at the meeting of the Commission on modernization and technological development of Russia March 30, 2011) or engineering and economic centers, based on leading engineering universities, first of all - national research universities. These new business models for the establishment of engineering-economic centers have the following features:

1. When developing engineering knowledge management phase business structure should have its own system of generating innovations, system of sales technology development and production updating, quality control.

2. Possession of engineering assets, which form a complete set of technology, is not mandatory, although desirable. Economic competences should be considered separately in accordance with a potential of the global services market, a detailed analysis of the globalization processes and cooperation in a specific area of engineering and real economy.

3. Managing the economic system in the phase of knowledge management supposes scheduling placement of orders (including third-party contractors) and improving of material flows.

ENGINEERING CENTERS AS SUBJECTS OF IMPLEMENTATION FOR ENGINEERING AND ECONOMIC DECISIONS

Basic engineering knowledge management strategies (Figure 2) require adaptation to the realities of the world market, in particular, a specific

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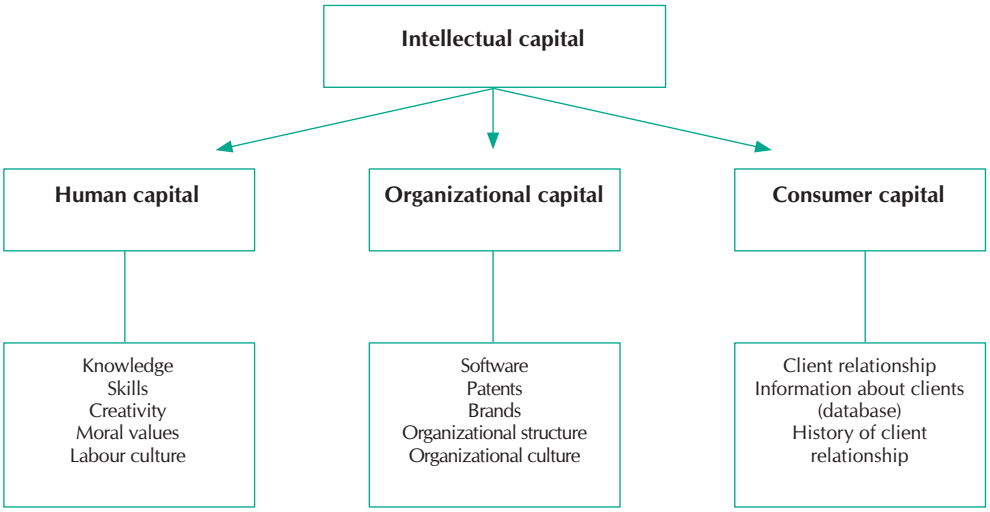
Figure 1. Structure of intellectual capital.

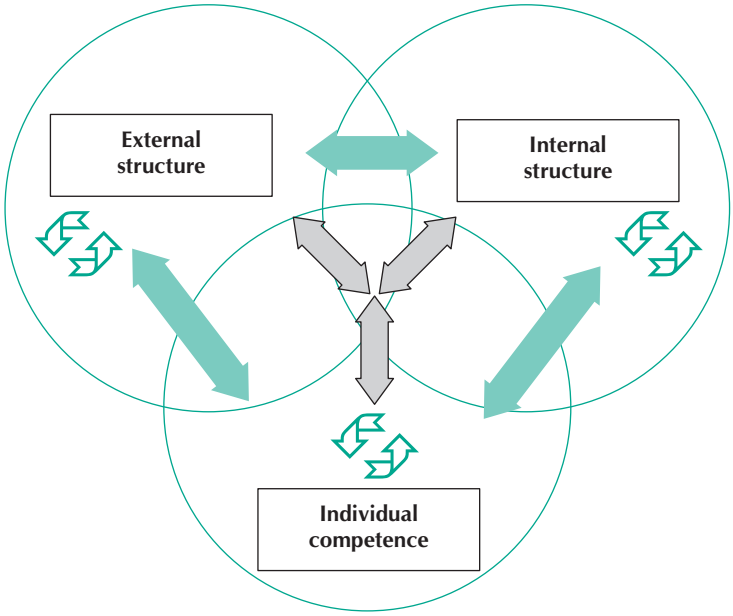


segment of the market associated with the procurement, processing and use of energy resources. Engineering knowledge management strategies are intended to create new value, realized in the products, people and processes with a rational formation and use of knowledge in organizations, particularly in engineering (engineering and economic) centers. The main objective of these strategies is to increase the efficiency of using all available resources of the organization, getting better and more rapid innovation, improved customer service, reducing the loss of unused intellectual assets. Engineering centers, whatever legal form is selected for their running, should be focused on the integrated use of engineering and engineering-economic skills of cooperative activity participants.

All possible strategies for the development and use of engineering knowledge in organizations can be represented as seven combinations of the basic strategies (Figure 2). Three of them are focused on efficient generation and use of knowledge in one of the types of intellectual capital (individual competence, internal structure and external structure). Three other strategies are supposed to achieve a positive effect on the interaction between two different types of intellectual capital (individual competence and internal structure, individual competence and external structure, internal and external structure). Finally, the last, seventh strategy is taking into account the simultaneous interaction of all three elements of intellectual capital (these strategies are conventionally shown in Figure 2 in the form of arrows of different shapes).

Thus, the basic strategy for the establishment of engineering centers should be directed either to the exchange of knowledge within a single type of intellectual capital in order to increase it, or the effective transfer of engineering knowledge from one form of intellectual capital to another. There is a clear correspondence between these two ways of determining the structure of intellectual capital and its substantive content. In engineering practice, especially related to energy problems, the effective transfer of knowledge can be considered as a major priority of engineering and economic centers.

Figure 2. Basic knowledge management strategies.



ENERGY PROBLEMS AS AN "EXPERIMENTAL FIELD" FOR IMPLEMENTATION OF ENGINEERING AND ECONOMIC DECISIONS

Organizational capital corresponds to internal structure; consumer capital corresponds to external structure, and human capital to staff competence. The specific content of these terms in the field of getting and using energy resources is as follows:

Staff competence (individual competence) – it is the ability to act in various situations, education, qualifications, skills, experience, energy and attitude to work, to clients, general level of culture.

Internal structure – it is the organizational basis of production, technologies background, patents, concepts, know-how, copyrights, computer and administrative systems, networking, organizational culture.

External structure - a relationship with customers, suppliers, competitors, social communities, brands, trademarks, image of an organization.

External structures are oriented to the market and the research methodology, besides, the development of market strategies are described in marketing terms. For the markets of engineering solutions aimed at improving the production structure, producing new goods and rendering landmark services, a new marketing direction called "Technology Marketing" has been formed / 12-15 /. It is important for the engineering center, which develops engineering-economic services in the areas of energy, to have a network structure to cover the maximum range of similar engineering problems, distributed over a vast territory. Local problems are quite rare in the energy sector, network structure of the modern energy tends toward globalization.

Spatial distribution of energy needs in Russia is a crucial factor when assessing energy efficiency of a technology platform. Energy transportation costs form an important part of the total costs. Study of the energy resources consumption over the past years has shown that in 2008 the total amount of consumed energy resources decreased almost in all Federal Districts of Russian Federation, which was obviously caused by negative consequences of the financial and economic instability (Table 1). However it was a

very slight decrease, indicating a constant demand for energy as a basically required element for development.

Since 2009, simultaneously with efforts to overcome the crisis in the country, there has been an increase in energy consumption by an average of 6-7% compared to 2008. At the moment Central Federal District (CFD) has the smallest energy density of the gross regional product (GRP) among other districts. Its economy is characterized by a high proportion of service industries and industries with low energy consumption. Siberian Federal District is distinguished by the highest energy density, where more than 70% of industrial production is energy-intensive industries such as metallurgy, chemical, petrochemical and others. The energy density of Siberian Federal District is 2.4 times greater than that of Central Federal District. Other federal districts are ranked in relation to CFD in the following order: Urals - 1.4 times, the Far Eastern - 1.5 times, Northwestern - 1.8 times; Southern - 1.9 times; Volga - 2 times greater. It is important to note that in the past five years, energy density in CFA decreased by 8%, in Northwestern Federal District by 10.4%; in Urals Federal District - by 26.5%, in Far Eastern Federal District by 12.8%.Knowledge management in the field of regional energy needs will permit to predict such changes and prepare for them.

Present high power consumption rate of the domestic economy is caused, to a large extent, by a number of reasons:

- use of obsolete and energy intensive technologies in manufacturing, transport and processing of energy resources;
- special climate conditions in most regions of the country, which are characterized by low annual mean temperature;
- significant amount of technologically obsolete equipment with a high wear rate;
- existing structure of the economy, characterized by a high share of energy intensive industries (over 60% of industry) and a relatively small share in GDP of services and businesses that meet the requirements of the modern "knowledge based economy";
- lack of developed innovative infrastructure.

Engineering solutions, based on the economic estimates of expected results, can make a significant contribution to improving energy efficiency of the real sector of the economy and developing energy saving at large. Entrepreneurial approach to implementation of such decisions can be based on the establishment of engineering centers. Contribution of these centers in the individual components of intellectual capital can be inequivalent, although the overall effect of the centers' establishment obviously will be positive.

The ratio between intellectual capital components in the engineering center is shown in Figure 2, where one can notice that the boundaries between three main types of intellectual capital are vague (conditional). Some elements of intellectual capital can be equally attributed to its various types. At the same time there are elements that correspond only to one or another form of intellectual capital. Human capital is described in detail in the economics literature. Moreover, for the development of human capital issues Nobel Prizes in Economics have been awarded (Theodore Schultz in 1979 and Gary Becker in 1992). Under the human capital it is usually understood a set of knowledge, skills and motivation, which everyone has. Rising educational level, accumulation of professional experience, personal relationships, better health, mobility, acquisition of information and competence mastering could be regarded as an investment in human capital. Intellectual capital is not additive. It basically cannot be decomposed into components so that the sum of their estimates would be equal to the overall assessment of the organization's intellectual capital such as engineering center. The interaction between different components is highly nonlinear. So, for example, only human component is not always sufficient enough for the development of a strong

Table 1. Energy resources consumption by Federal Districts of Russian Federation, million tonnes of coal equivalent

Federal District	2006	2007	2008	2009
Central	181,4	187,3	190,1	176,0
Northwestern	95,7	97,3	98,0	97,4
Southern	91,4	95,8	96,3	95,6
Volga	179,2	185,5	191,1	189,0
Urals	199,1	207,9	205,2	202,7
Siberian	147,2	150,0	149,8	136,7
Far Eastern	42,6	42,6	46,2	44,8

**- according to Russian Federal State Statistics Service*

intellectual capital. This requires high competence of the engineering staff to complement the corresponding elements of structural capital such as organizational structure, information technology, administrative procedures, etc. A vital role plays the network structure of the engineering center itself. This network structure can be based on specific structural units of a high school, where an engineering center is established. For instance, National Research Nuclear University "MEPhI" (NRNU MEPhI) has more than twenty separate divisions (branches) in 12 federal subjects located in 5 federal districts. Thus, engineering solutions, developed for example in the organizations of Central Federal District, can be replicated in the organizations of other federal districts taking into account local features. Consideration of the local features (climate, etc.) should be carried out by engineering employees. These employees may be professors and graduate students of NRNU MEPhI separate divisions.

Information technologies make it possible to mobilize the potential of human capital and turn its development vector towards improving of the external structure: market interaction with customers, competitors, social structures. Entrepreneurship in engineering should be accompanied by the development of specific business education. Unlike traditional forms of business education (MBA, etc.) this kind of education should allow for acquiring a combination of engineering and economic skills within the training process. Engineering and economic education was developed in the former socialist form of economic activity, but over twenty years of transition it has virtually disappeared. Economic education in general is focused on non-productive structure: banking, stock transactions, insurance business, etc. Over the years pedagogical staff has also changed, engineering competence has disappeared from the teaching practice. Establishment of engineering (engineering and economic) centers, stated as a problem in the last president's orders, should be supported by the engineering community along with the government support provided by the federal bodies of executive power. Security issues in engineering practice / 18.19 / should also be reflected, when designing and implementing educational programs. In this case engineering will receive a new impulse for its development and the output effect will be seen in all segments of the real economy.

CONCLUSION

We are still to find and test mechanisms for creating organizational and legal form of the engineering centers. However, the competence content of such centers could be assessed today. Entrepreneurial potential in Russia is mainly concentrated in the financial, banking, insurance sector and other non-industrial capital investment spheres. In the real sector of economy except for the oil and gas sector, which gives an immediate quick return on invested intellectual capital, it is difficult to mention some remarkable engineering achievements that had a significant impact on business projects.

Efficient application of the described in the article knowledge management features and improvement of present situation is possible only with an intensive and conscious state support in training and retraining of engineering personnel with a focus on business implementation of engineering achievements. As a tool for assessing the prospects of any engineering design (i.e. engineering and economic center) we can use an approach for development of a knowledge management system, involving the methodology of technological marketing.

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