Forming system of strategic innovation management at high-tech engineering enterprises

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Abstract. The article considers the processes of forming the strategic system of innovative activity management at the enterprises of a high-tech mechanical engineering complex (MEC) that are traditionally decisive in shaping the economic base of Russia. The authors proposed a method of designing a strategic system of innovative activity management at the MEC's enterprises of the region which is based on the consideration of means and opportunities of the enterprise to implement intellectual activity. The proposed methodology and the empirical results constituted a ground for developing a system of strategic innovation management when performing the state-guaranteed order at the hi-tech MEC enterprises. Its implementation will help to reduce the level of uncertainty throughout the entire life cycle of an innovative activity product.

1. Introduction

In the context of the country's transition to innovation-oriented post-industrial economy with a significant intensification of state innovation support, we witness a continuous decline of innovative competitiveness and efficiency of the high-tech mechanical engineering enterprises due to the low level of their strategic management efficiency. However, under conditions of high rates of the world's scientific and technological development, stimulation of innovative activity in mechanical engineering is not only important for the competitiveness of the national engineering production, but also for the development of related industries utilizing mechanical engineering products. We develop a methodology taking into account the resources application potential to improve the degree of implementation of innovations into the high-tech enterprises of the machine-building complex (MEC). The conducted systemic analysis of the strategic innovation management at the one of MEC enterprises leads to the conclusion that processes of strategic innovation management in such enterprises are quite random and insecure.

The developed methodology is based on determining a horizontal resource potential of strategic innovation management and allows one to determine the potential of resources application at each stage of the product lifecycle [1]. Comparison of actual and theoretical values of the horizontal resource potential will allow us to adjust the distribution of each resource within the stage and thus to optimize the implementation of the given tasks at a particular stage [2]. On the basis of the proposed

methodology and the empirical results, we developed a scheme of strategic management of innovative activity. It is supposed that its implementation will help to reduce the level of uncertainty throughout the entire life cycle of product innovation when performing the state-guaranteed order at MEC enterprises.

2. Materials and methods

The methodological base of the research is represented by the method of analysing financial results of enterprises to assess their sustainable development [3], methodological apparatus of rating estimation of their financial and economic state [3], methods of evaluating the effectiveness of the innovative projects implementation at the enterprises [4], methods of evaluating and analysing competitiveness and sustainable development of mechanical engineering enterprises [5].

The study was conducted in two directions. The first direction is devoted to the investigation of the functional elements of the integrated methodology for calculating the resource potential of the enterprise. The second direction is related to obtaining specific results defining a set of tools and capabilities of the enterprise in implementing intellectual property, and it will be based on the results obtained in the first study [6]. After analyzing and synthesizing ways to optimize the existing system of strategic innovation management, we analyzed the horizontal distribution of resources within each stage of the product life cycle, the vertical distribution of each kind of resources at all stages. Then the results were summed up into a single model to develop recommendations how to optimize the existing system. Expert assessment was conducted through the survey of senior and middle managers at one of the high-tech mechanical engineering enterprises of the Siberian Federal District (SFD). The results were processed by the method of mathematical statistics.

3. Situation Analysis in the industry

The most active sphere of implementing innovations in mechanical engineering according to the number of companies investing in innovation is a sub-sector of producing electronic and optical equipment: new products or technologies are developed at about 30% of enterprises (figure 1). The same situation is observed if only technological innovations are taken into account (figure 2).

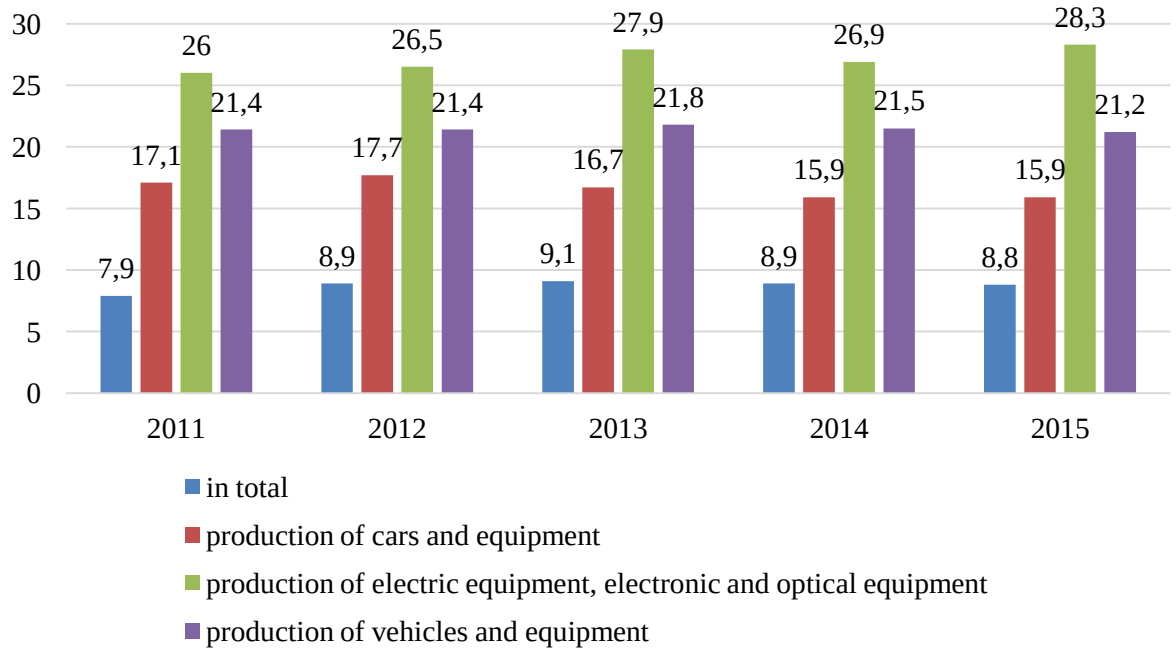

Figure 1. The share of mechanical engineering enterprises engaged in innovation in 2011-2015, as

compared to the data for the whole Russian economy [7]

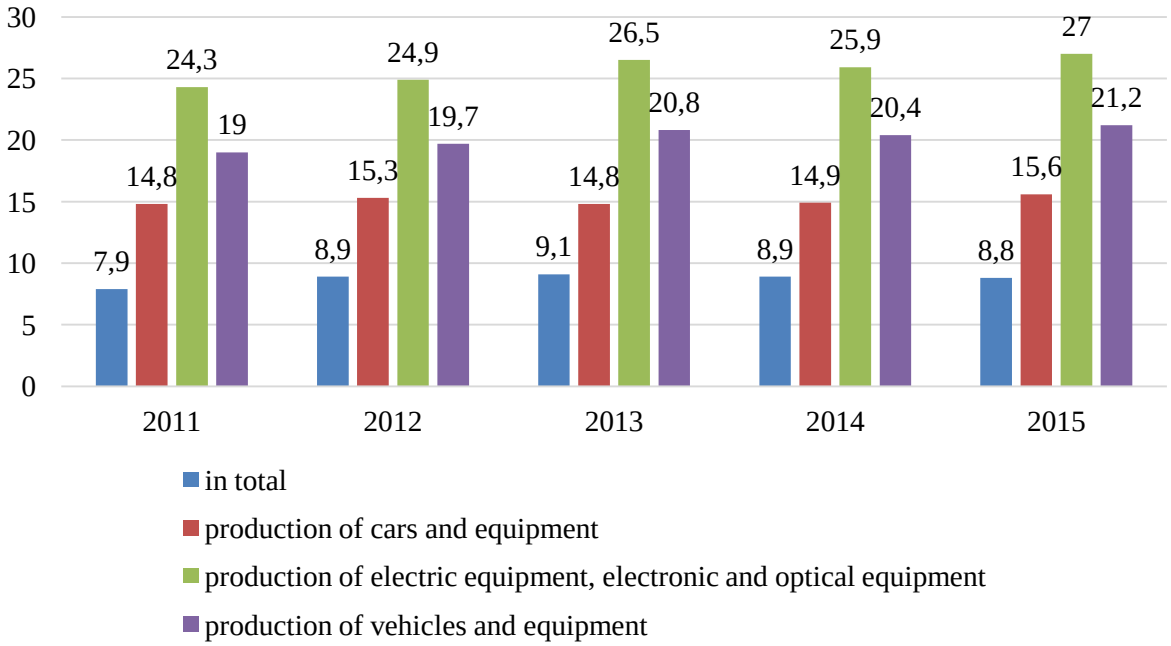

Figure 2. The share of mechanical engineering enterprises engaged in technological innovation in 2011-2015, as compared to the data for the whole Russian economy [8]

The extent of financial investments aimed at promoting technological innovations shows a stable upward trend though it was a slight decrease in 2015. In 2015, these expenses amounted to 735.8 billion rubles that is lower by 11% in fixed prices as compaired to 2014. About two thirds of the technological innovation costs belong to the most economically successful industries, such as extractive industries (17.1%), automotive industry (7.9%), production and distribution of electricity, gas and water (6.3%), metallurgy (5.9%), aircraft and spacecraft manufacturing (5.4%). Expenditures on technological innovation are mainly related to the introduction of process innovations aimed at enhancing the effectiveness of production processes: their share exceeds 64% of the total investments. The costs of pioneering product innovations implying a significant breakthrough in product manufacturing are 1.8 times lower (35.9%). It is compared favorably with high-tech and separate medium-tech sectors (chemical industry, automotive industry, machinery and equipment production) where the share of product innovation costs is about three-quarters of total expenditures on innovation. The intensity of technological innovation expenditures in industrial manufacturing amounted to 1.8% in 2015 (versus 2.1% in 2014). In high-tech sectors, the figure is three times higher (5.9%), and, in some industries, it reaches maximum values comparable to global counterparts (for example, in medical equipment and appliances manufacturing - 6.6%).

Figure 3 demonstrates the comparison of indices characterizing the dynamics of the turnover, the costs of technological innovation and manufacturing innovative products, and proves the absense of a clear dependence between these indicators.

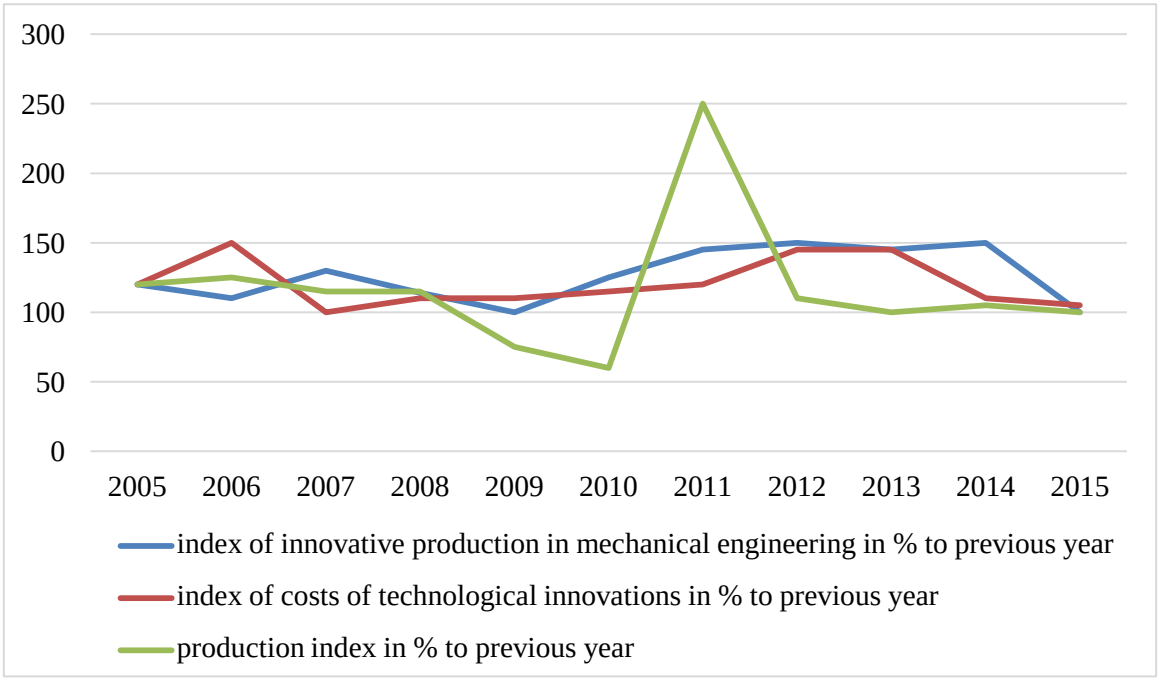

Figure 3. Comparison of indices characterizing the production and innovation of engineering enterprises in 2005-2015

At the same time, fluctuations of technological innovation costs are smoother and have lower amplitude as compared to other indicators. This can be explained by the fact that the investment programs for the machine-building enterprises are medium and long term while the dynamics of production volumes both of innovative products and output as a whole is more susceptible to the economic crisis. In addition, strategic management at the organizational level, including innovation activities, at the high-tech mechanical engineering enterprises is relatively new in Russia as it was previously common to carry out only operational management for individual projects.

It should be noticed that machine-building enterprises are first increasing innovative products volume when exiting the crisis (after the crisis of 2008, the innovative products volume increased in 2012 while total output reduced). This brings us to the conclusion that innovative products manufacturing contributes greatly to the anti-crisis measures. Thus the research of the impact of strategic management methods in the innovative sphere of high-tech machinery enterprises, of their further development in order to enhance economic efficiency proves to be highly relevant.

4. Study procedures

On the basis of product life cycle stages and existing traditional resource types, the study encouraged the development of methods to measure the horizontal resource potential of the strategic innovation management of innovative at the n-th stage [9]. The methodology allows defining the resource application potential at each stage of the product life cycle, as well as to redistribute and manage resources most efficiently within each stage. Thus regarding the already conducted study [10], the horizontal potential of applying resources for the strategic management of innovative activity at the n-th stage of the product life cycle can be calculated as additive components with weight coefficients:

$$P_n = k1K_n + k2L_n + k3M_n + k4I_n, \quad (1)$$

where K_n is financial resources at the n-th stage of knowledge generation, L_n - labour force at the n-th stage, M_n - material resources at the n-th stage, I_n - information resources at the n-th stage.

In order to assess specific types of resources, it is necessary to determine:

1) the payroll normalized to the number of employees participating in performing a specific stage of the product life cycle;

2) the share of the human resources at every stage of the product life cycle equated to the share of employees who are in charge of performing this stage;

3) distribution of material resources based on a cost component of a technical upgrading plan for each stage of the product life cycle, but a cost component is standardized throughout the technical upgrade plan;

4) the share of information resources in terms of information and computer support at every stage of the product life cycle.

Comparing actual and theoretical values will allow one to adjust the distribution of each resource within the stage and thus to optimize the implementation of the tasks at a particular stage [11].

In order to assess the real resource potential of strategic innovation management, we used data received from the industrial activity report of one large state-owned MEC enterprise in the SFD in 2016. According to life cycle stages of the product, the actual data on the use of resources were measured at each stage and then compared with the ideal values. To obtain ideal values of resource allocation, senior and middle managers were interviewed at the enterprise [12]. The actual measurement data are accurate as every stage of the product life cycle is carried out by different departments of the enterprise [13]. Then the received percentages of financial, human, material and information resources are normalized for each phase in order to obtain the allocation of resources at every stage of the product life cycle.

In support of the proposed methodology for MEC enterprises in the region, a schematic diagram is given to visually represent the strategic management of innovative activity when performing the state-guaranteed order. The proposed scheme of strategic management of innovative activity helps to increase the efficiency of each stage. As a result of implementating the scheme of strategic innovation management, the commissioning dates are reduced and the number of warranty repairs decreases. In general, the implementation of the given scheme at MEC enterprises leads to decreasing the level of uncertainty throughout the product life cycle and consequently to reducing the deadlines and increasing the quality of executed works which inevitably results in increasing the effectiveness of the state-guaranteed order.

5. The results of the empirical research

On the basis of the above mentioned methodologies, we have studied the system of generating knowledge at the MEC enterprise and obtained ideal and empirical values of the horizontal distribution of resources throughout the product life cycle (table1).

Table 1. Ideal (I) and empirical (E) elements of the contribution value of the resource potential of innovation (%)

Stages of the product lifecycle	resource allocation									
	labor		material		financial		information		total	
	I	E	I	E	I	E	I	E	I	E
marketing research	45	20	15	25	30	15	10	40	100	100
simulation	50	23	20	26	20	11	10	40	100	100
software	40	20	20	16	30	32	10	32	100	100
engineering	40	21	15	21	35	5	10	53	100	100
technology development	25	28	25	31	10	27	40	14	100	100
manufacturing	25	28	25	31	10	27	40	14	100	100
test	15	28	40	27	20	22	25	23	100	100

It should be noted that the ideal allocation of resources, according to respondents, is optimal for functioning of MEC companies and does not depend on a specific state-guaranteed order. Comparing empirical data and weighting coefficients of the theoretical horizontal capacity of using resources shows significant discrepancies in actual and theoretical values of used resources persentage at each stage of the product life cycle [14]. The stage of research and marketing analysis shows a significant redistribution of resources towards increasing the share of information and financial resources. The second stage of the product life cycle - the stage of technical specifications preparation, research, documentation and modeling – indicates a significant increase in the proportion of material and financial resources in comparison with theoretical estimates, but a significant decrease in the use of labor resources [15]. The analysis of the third stage of the product life cycle - the stage of developing electric circuits and software – demonstrates redistribution of resources so that the material and information ones underwent an increase in the amount, but the use of the labor force decreased twice as compared with the theoretical model. The results of the fourth stage - the stage of developing the design documentation – reveals redistribution of resources towards the material ones. At the same time, there was a noticeable decline in actual levels of labor and information resources application in comparison with theoretical model estimates. The analysis of the fifth stage of the product life cycle - the stage of developing technical documentation – shows that the resources are redistributed again and this time financial and information resources experience a significant increase. Obviously, these processes reflect the decline in the use of labor and material resources at this stage of the product life cycle. At the sixth stage of the product life cycle - the stage of manufacturing products – the increase in employing labor and financial resources comes with a decrease in using information resources in comparison with theoretical estimates. When analyzing the seventh stage of the product lifecycle - stage of product testing - it is visible that resources are redistributed towards the use of labor forces to compare with theoretical estimates. But this process is accompanied with the parallel decline in applying financial resources.

Comparison of theoretical (potential) and actual estimates provides data on development reserves for strategic innovation management when a real production process is organized. Thus the analysis of empirical data makes it possible to define the more likely way of optimizing the use of each resource apart and at every stage of the product life cycle.

6. Conclusion

Developing the integrated methodology of strategic management of innovative activity at the MEC enterprises in the region as a set of enterprises assets and capabilities when implementing intellectual property allowed obtaining the following theoretical and practical results. Firstly, the proposed theoretical methodology allows evaluating the capabilities of the enterprise in implementing intellectual activity. Secondly, a scheme of strategic management of innovative activity is developed to effectively perform the state-guaranteed order; its implementation contributes to a reduction of the degree of uncertainty throughout the entire product life cycle and, as a result, to a shortening of the implementation period and to improvement of the quality of all performed work. It inevitably leads to an increase in the effectiveness of performing the state-guaranteed order. Thirdly, the empirical research becomes the blueprint for determining the real proportion of allocated resources at every stage of the product life cycle at the high-tech engineering enterprises. The proposed methodology accounts for the potential use of resources to improve the effectiveness of the strategic management of innovative activity at the high-tech engineering enterprises as an engine of innovation in the region is able to improve efficiency of production at MEC enterprises and thus to increase the level of innovative development of the given region.

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