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New Item: Potential of Knowledge Generation

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Abstract. The resource potential of knowledge generation, consisting of the set of tools and capabilities for the implementation of the intellectual activity of the enterprise, is developed on the basis of the lifecycle of products for industrial enterprises. Weighted coefficients are expertly determined by the application of resources at each phase of the intellectual activity algorithm. Formalised resource use weighting coefficient values are compared with the actual work carried out by a major state-owned enterprise. A direction for the optimal use of resources to meet actual production orders is formulated by differences between theoretical and actual potentials.

Keywords: Industrial enterprises, knowledge generation, intellectual activity, resource potential, economic institutions, optimisation

1. Introduction

The development in the XXI century is characterized by the growth of high-tech industries and knowledge-intensive technologies. It has caused a transition to a new qualitative level of development of knowledge economy. It is type of economy, where the main growth factors are knowledge and human capital. Development of knowledge economy includes such elements as improving the quality of human capital in the knowledge production of high technology, innovation and high quality services. Russian hi-tech industry includes primarily state-owned enterprises, which produce a large part of scientific-research and experimental-design works according to the statistic. The rapid development of a knowledge-based economy places special demands on the institutional structuring of business and creativity. The purpose of the present study is the development of a new economic concept – the resource potential of the generation of knowledge as a set of resources and capabilities of enterprises in the implementation of intellectual activity. The structure of the paper is as follows: The second section presents the analysis of the main publications. The third characterizes the methodology for assessment of the resource potential of the generation of knowledge. The forth section describes the results of the empirical research of potential of knowledge generation. The fifth section is the conclusion.

2. Analysis of the main publications

Problems related to production processes and the uses of new knowledge in the economic activity of economic subjects have been studied in many areas of economic theory. J. Schumpeter attached great importance in his writings to the role of new knowledge in economic processes. This knowledge is regarded as a "subjective" quantity, i.e. not subject to formalisation; the influence of knowledge on economic processes is studied by means of dynamic changes occurring in economic life (Schumpeter, 1952).

In order to assess the significance of knowledge, F. Machlup proposed the following typology of knowledge: 1) practical knowledge; 2) intellectual knowledge; 3) small-talk and "entertainment" knowledge; 4) spiritual knowledge; 5) unwanted knowledge (Machlup, 1966).

F. Machlup based the construction of his typology of knowledge on the possibility of using new knowledge in various spheres of economic activity. Because economic activity can only rely on formal knowledge, the constructed typology considers only the distinct area of new knowledge that is comprised by explicit knowledge. Taking tacit knowledge into account for the first time, I. Nonaka proposed distinguishing types of new knowledge according to their degree of formality. All new knowledge can be divided into explicit and implicit (or tacit) knowledge (Nonaka, Takeuchi, 2003). Institutions of explicit and tacit knowledge generation provide information on optimal customer service, helping to overcome financial crises (Cuesta, 2010).

In this connection, for manufacturing companies, taking Schumpeter's multiple phases of the creation of new combinations into account, institutional support for knowledge generation should include a significant number of institutions of market analysis, management, development, programming, technological training, etc.

A considerable amount of current research is devoted to solving problems concerning the knowledge economy. For example, in investigating the relationship between the development of knowledge and economic growth (Lever, 2002), and evaluating the state's influence on the development of the innovation system (Miethling, 2014), the constraints of knowledge generation (Sarewitz, 2010), and the development of rules of social activity in the formation of regional innovation systems (Fiore, Grisorio & Prota, 2011).

The recognition of knowledge for the success of the organization and the need to take advantage of them, has led some researchers to propose methods that are useful to manage this high-value knowledge efficiently (Dangelico, 2008; Karami, 2006; Kurtossy, 2004; Nonaka, 2007; Garengo et al, 2005; Gold et al, 2001). In scientific literature, the problem of evaluation of knowledge creation at industrial enterprises devoted a lot of attention. Various methods of determining the effectiveness of the new knowledge was considered by Malkova (2012), Pogorelskaya (2009), Dudyasova V., Kipel N., Smirnova E. (2012). The authors Bocharova M. A. and Kouzmina A. A. (2010) proposed to use the value of intellectual capital for the evaluation of the system of knowledge generation at industrial enterprises. Nonaka and Toyama (2005) developed dynamic models that allow the development of capacities to transfer and combine knowledge in companies. Jugdev (2007) proposed that the companies most likely to achieve successful innovation would be those that are able to learn how to create, transfer and manage knowledge. Existing studies indicated that state ownership could stifle innovation and R&D in firms (Berliner, 1976). Some theoretical work showed that R&D activities in state-owned sectors were less efficient than those were in private sectors (Qian&Xu, 1998; Zhang and all, 2003).

A special place is given to research into the processes of education and knowledge generation (Bonett, 2000; Panikarova, 2015) in the overall landscape of the knowledge economy (Brown, Hesketh, 2004), including the role of individual scholars participating in intellectual activities and places at universities (Foray, 2004).

Thus, as shown in some publications, the study of the processes of research and formation of innovation policy requires systematic evaluation (Arnold, 2004). Such systematic evaluations may be carried out on the basis of institutional structures that reflect real processes of knowledge generation in the workplace.

Although there is extensive literature focused on the features of knowledge creation in state-owned enterprises, there is not an adequate approach to develop a methodology for measuring of the resource potential of the generation of knowledge as a set of resources and capabilities of enterprises in the implementation of intellectual activity. At the same time, an analysis of current developments shows that there is a lack of institutional research on resource support for knowledge generation processes.

3. Methodology

3.1 The Product Manufacturing Facility Lifecycle

One of the first to draw attention to the distinction between the generation of knowledge (inventions) and innovations was Joseph Schumpeter. In his 1912 study entitled "The Theory of Economic Development", Schumpeter noted that "new discoveries and inventions are constantly replenishing the existing stock of knowledge... The function of the inventor and the general technician does not coincide with the function of the entrepreneur. As such, the entrepreneur is not the spiritual creator of new combinations (*of resources)*" (Schumpeter, 1952).

According to Schumpeter, the realisation of new combinations by entrepreneurs involves the following five circumstances: "(1) the creation of a new quality of goods; 2) the introduction of a new mode of production; 3) the development of a new market; 4) the identification of a new source of raw materials; 5) the carrying out of an appropriate reorganisation" (Schumpeter, 1952).

Thus, for Schumpeter, innovations (to the first and second case of the activities of an entrepreneur) precede inventions, i.e. the creation of new discoveries and patents.

It should be noted that the development of innovative systems is in turn dependent on the development of systems of knowledge generation, which stimulates the development of actual production (Howells, Roberts, 2000).

Thus, the lifecycle of scientific and technological activities consistently includes three phases: inventions (new knowledge, patents) – innovation (introduction of new knowledge) – imitation (replicating the introduction of new knowledge).

The lifecycle of products in industrial enterprises may include the following steps: 1) research and marketing; 2) preparation of technical specifications and modelling; 3) development of schemas and software; 4) development of design documentation; 5) development of technical documentation; 6) manufacturing of products; 7) testing of products (Popov, Vlasov, Shishkina, 2015).

Resource planning occurs in two phases: the market research / analysis phase and the design and technological documentation phase.

The study is conducted during the market analysis phase, which takes place following the receipt of the order to the production company. The company collaborates with the primary enterprise by means of competitions and tenders and with business organisations by means of competitions or by conducting independent market research (Lehoux, Daudelin, Denis, Miller, 2008). As a result, tender documents containing information on the required resources are developed in the form of technical proposals and terms of reference for the development of research documentation, simulation, software development and information security. In other words, the material, human, information and financial resources determine the initial implementation of the first five phases of the product lifecycle. Within the framework of the research, the company collaborates with universities and research organisations (Stiekema, 2005) for the creation of joint laboratories, formation of educational research facilities and operation of departments on the basis of the enterprise (Leon, Fernandez, Flores, 2011).

Detailed processes of production and testing of the product, an analysis of the market for necessary materials and components, technological specifications for development of software and information support of production processes, the planning of the number of employees and generation of estimates – that is to say, the planning of all kinds of resources for the production and testing phases – are developed at the design and technological documentation development phase (Gulcan, Akgungor, Kustepeli, 2011).

Resource planning comprises the formation of institutions of knowledge generation in accordance with the phases of the product lifecycle. The institutions of knowledge generation are listed in Table 1 alongside the results of intellectual activity.

From the following table it can be seen that each phase of the product lifecycle corresponds to certain institutions of knowledge generation in which the results of inventive activities are produced.

3.2 Theoretical use potential of knowledge generating resources

The use potential of knowledge generation resources can be schematically depicted as a cube (Fig. 1) by analogy with the enterprise market potential (Popov, 2004).

The use potential of knowledge generation resources at the n-th phase of the product lifecycle can be calculated using a term addition formula with weighted coefficients:

$$P_n=k_1K_n+k_2L_n+k_3M_n+k_4I_n, \qquad (1)$$

where K_n is the sum of financial resources required up to n-th phase of the generation of knowledge; L_n is the quantity of labour resources to the n-th phase; M_n is the quantity of material resources to the n-th phase; I_n is the quantity of information resources to the n-th phase.

The evaluation of weighting coefficient terms in (1) was performed by the expert survey method. As a result, the following results were obtained.

Table 1: Institutional support for the various phases of the product lifecycle

Product lifecycle phase	Corresponding institutions of knowledge generation	Results of intellectual activity
1. Research, marketing	- Institution of market analysis. - Institution of primary market research of purchased components and materials	1. Know-how; 2. Patents; 3. Publications; 4. Scientific reports; 5. Marketing reports; 6. Tender documentation; 7. Patent research.
2. Terms of reference, research documentation, modelling	- Institution of development management. - Institution of marketing management.	1. Conceptual design; 2. Technical proposals; 3. Scientific-technical report; 4. Invention; 5. Publication; 6. Leading enterprise standards.
3. Development of electrical schemas, software	- Institution of circuit design and programming.	1. Technical report; 2. Methodologies; 3. Private technical tasks; 4. Publications; 5. Inventions; 6. Computer programs.
4. Development of design documentation 5. Development of technical documentation	- Institution of design-technological preparation of production. - Institution for the purchase of components and materials	1. Technical Reports; 2. Enterprise Standards; 3. Technical Conditions; 4. Technological Processes; 5. Inventions.
6. Manufacture of products	- Institution of manufacturing. - Institution of technical control	1. Industrial designs; 2. Programmes for industrial equipment.
7. Product testing	- Institution of quality control.	Test certification

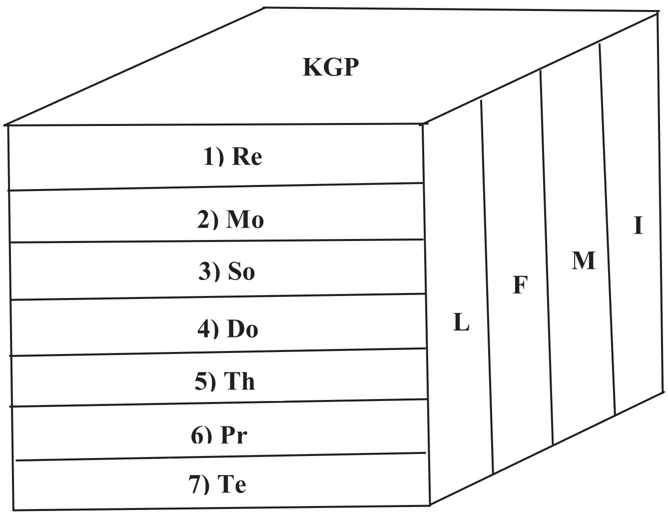

Figure 1: Schematic representation of the resource potential of knowledge generation KGP (Knowledge Generation Potential).

Here: Re – research; MO – modelling; So – software; Do – development of documentation; Te – technology support; Pr –product manufacture; Te – product testing; L – labour resources; F – financial resources; M – material resources; I –informational resources.

Phase 1. Research, marketing

The proportion of the use of human resources is greatly increased at the first phase of research and marketing following receipt of an order. This is due to the need for developing an overall plan for the product. As a consequence, there is a need for highly skilled personnel in various scientific fields. However, just as there is a high proportion of information resources in the first phase, so special knowledge is required for research; and, for the realisation of calculations, the necessary software. On the other hand, the proportion of financial and material resources is significantly lower due to the absence of production and technical processes and the reduced need for providing expensive workstation equipment. Accordingly, the resource potential of knowledge generation in the first phase appears in the following form:

$P_1=0.15K_1+0.5L_1+0.05M_1+0.3I_1$ (2)

Phase 2. Terms of reference, research documentation, modelling

At the phase of creation of technical specifications, preparation of research documentation and modelling, the human resource continues to be primary. The reason is the same, consisting in the need for highly skilled personnel having the ability to solve highly complex challenges. With regard to the information resources, these are lower than in the first phase due to the fact that the work performed is based on previously obtained information and knowledge; however, an additional software requirement remains. Financial resources have the same proportion as information, but slightly higher than during the previous phase, due to the additional funding of the software. The proportion of material resources is gradually increasing due to the provision of jobs. Consequently, the knowledge generation resource potential in the second phase consists of the following components:

$P_2=0.2K_2+0.5L_2+0.1M_2+02I_2$ (3)

Phase 3. Development of electrical schemas and software

At the phase of the development of electrical circuits and software, the greatest role is still given to human resources, although, in comparison with the previous step, their proportion has declined in favour of information resources. This can be explained by increasing demand for software and the need to develop the database. The resource potential of knowledge generation in the third phase is as follows:

$P_3=0.2K_3+0.4L_3+0.1M_3+0.3I_3$ (4)

Phases 4 and 5. Development of design and technological documentation

Phases 4 and 5 comprise the development of design and technological documentation. A large proportion of this is formed of human and information resources since it is precisely in terms of highly skilled techniques, computer programs, standards and technological conditions that the created processes are described. The proportion of material and financial resources is not as significant since the material base does not require significant financial investments during this phase. The knowledge generation resource potential of the fourth and fifth phases can be described as follows:

$P_4=0.15K_4+0.4L_4+0.1M_4+0.35I_4$ (5)

$P_5=0.15K_5+0.4L_5+0.05M_5+0.4I_5$ (6)

Phase 6. Product Manufacture

The product manufacture phase requires the purchase of new equipment, production lines; here new production units and new modules are being developed. This explains the high proportion of material resources, as well as the increasing share of finance. At this phase, human resources are still of great importance, although their value is lower than in the previous one. This is explained by the organisation of the production process and debugging of the technology. The proportion of information resources is reduced, which is connected with the lack of research; on the other hand, processes leading to improvements in the software for the equipment are continuing. The knowledge generation resource potential at the sixth phase can be represented as follows:

$P_6=0.25K_6+0.25L_6+0.4M_6+0.1I_6$ (7)

Phase 7. Product testing

During the phase of testing of the finished product, considerable financial resources are required. This is due to the creation of conditions for the organisation of the systems to set up and monitor the quality of the product. This explains the high proportion of material resources. The knowledge generation resource potential during the seventh phase is as follows:

$P_7=0.4K_7+0.15L_7+0.25M_7+0.2I_7$ (8)

4. Results and Discussion

4.1 Empirical research procedure

In order to assess the actual resource potential of knowledge generation, the study used the 2015 data relating to the production activities of one of the large state-owned enterprises of the Russian military-industrial complex.

Actual data on the use of resources was measured at every corresponding stage of the product lifecycle. Such measurement corresponds to accurate data since every stage of the enterprise product lifecycle is carried out by different departments.

Accrued payroll, normalised by the number of workers participating in the realisation of a certain phase of the product lifecycle, was identified as a means for evaluating financial resources. The proportion of the labour force at every stage of the product lifecycle was equated to the percentage of workers responsible for the implementation of this stage. The distribution of material resources was determined on the basis of the cost of the constituent technical re-equipment plan for each stage of the product lifecycle, normalised across the entire technical plan. The proportion of information resources is evaluated according to the share of IT support at every stage of the product lifecycle.

These phases of manufacture of the product percentages of financial, human, material and information resources were then normalised for each phase in order to obtain the allocation of resources at every stage of the product lifecycle.

4.2 Results of empirical research

As a result of the study, the following distribution of resources throughout the product lifecycle was obtained (Table. 2)

Table 2: Empirical values of the elements of the knowledge generation resource potential (%)

Stages of the product lifecycle (PLC)	Allocation of resources				
	Labour	Financial	Materials	Informational	Total
Research, marketing	24	23	15	38	100
Modelling	23	26	11	40 %	100
Software	20	16	32	32	100
Construction	21	21	5	53	100
Development of technologies	30	31	9	30	100
Product Manufacture	28	31	27	14	100
Product testing	28	27	22	23	100

A comparison of the empirical data and weighting coefficients of the theoretical potential of the use of resources shows significant differences between the actual and theoretical values of the proportions of resources used at each stage of the product lifecycle.

For example, at the conclusion of the research and marketing analysis phase we see the following results (Fig. 2).

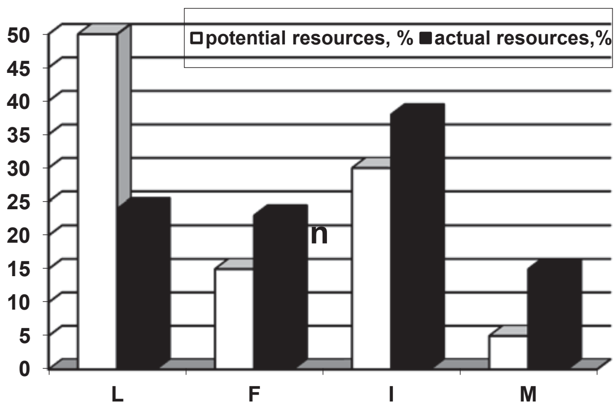

Figure 2: Allocation of knowledge generation resources during the research and marketing analysis phase – potential and actual resources in %. Hereinafter: L – labour force; F – financial resources; M – material resources; I – information resources.

It is apparent that there is a significant redistribution of resources leading to an increase in the proportion of information and financial resources.

In the second phase of the product lifecycle – the stage of preparation of technical specifications, research, documentation and simulation – the following results were obtained (Fig. 3).

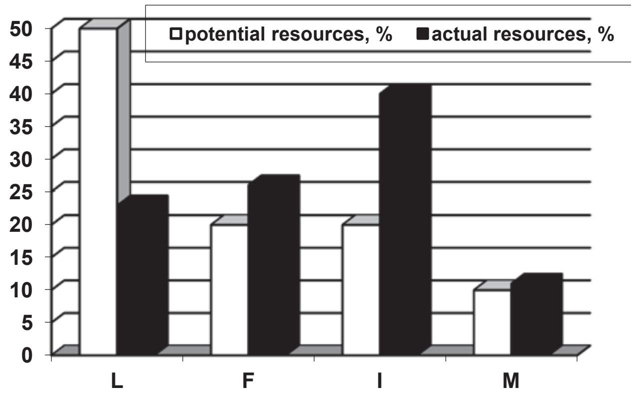

Figure 3 Allocation of knowledge generation resources during the drawing up of technical tasks phase – potential and actual resources in %.

During this phase, the proportion of material and financial resources significantly increases in comparison with theoretical evaluations; however, the use of labour resources is significantly reduced.

In the analysis of the third phase of the product lifecycle – the phase of the development of electric circuits and software – the following results were obtained (Fig. 4).

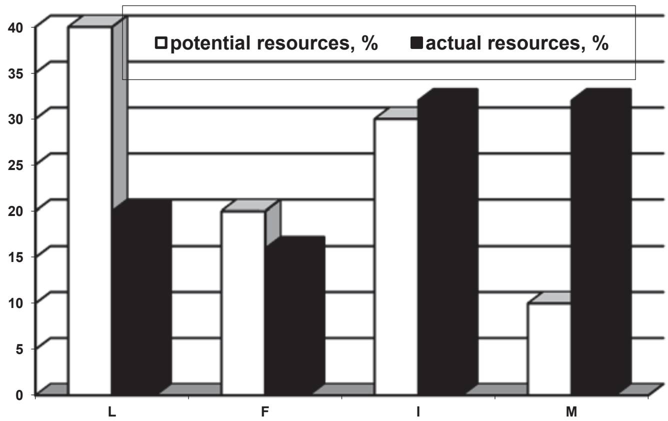

Figure 4 Allocation of knowledge generation resources during the phase of development of electrical schemas and software – potential and actual resources in %.

Here we observe a redistribution towards material and information resources: the use of information resources has more than tripled in comparison with the theoretical prediction, whereas the use of the labour force has halved in comparison with the theoretical model.

In the course of research into the fourth phase of the product lifecycle – the phase of the development of design documentation – the following results were obtained (Fig. 5).

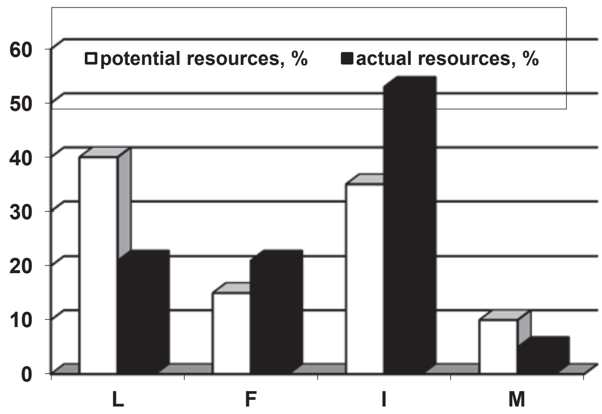

Figure 5: Allocation of knowledge generation resources during the phase of design documentation – potential and actual resources in %.

Figure 5 shows a reallocation of resources in the direction of the material. At the same time, there is a noticeable decrease in the actual levels of use of human resources and information resources in comparison with the theoretically modelled estimates.

When analysing the fifth phase of the product lifecycle – the phase of the development of technological documentation – the following results were obtained (Fig. 6).

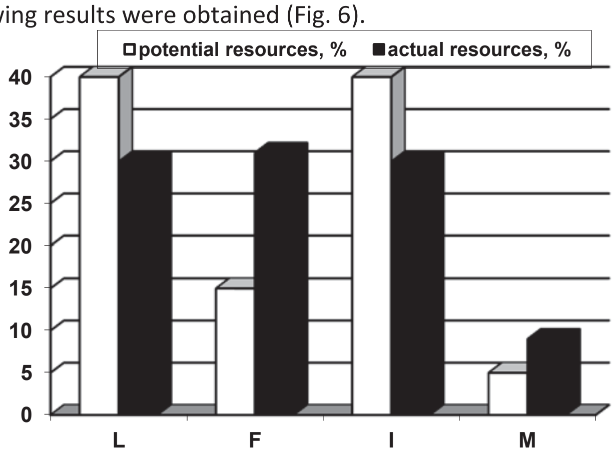

Figure 6: Allocation of knowledge generation resources during the phase of design documentation – potential and actual resources in %.

Here resources are reallocated in the direction of a significant increase in the proportion of financial and information resources. The probability is that these processes reflect the reduction in the use of labour and material resources at this stage of the product lifecycle.

During the sixth phase of the product lifecycle – the product manufacturing phase – the following results were obtained (Fig. 7).

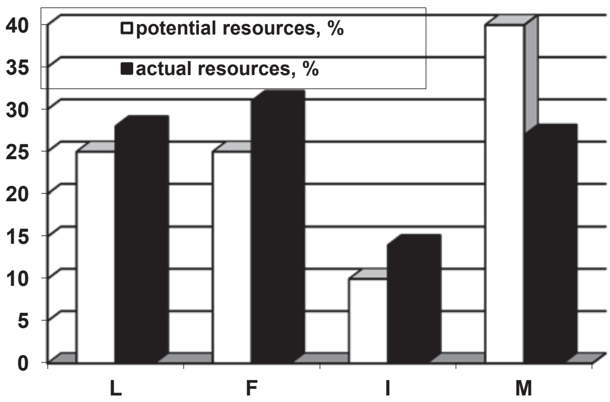

Figure 7: Allocation of knowledge generation resources during the product-manufacturing phase – potential and actual resources in %.

At this stage, the use of human and financial resources increases in comparison with theoretical predictions, but the use of information resources decreases.

As a result of the analysis of the seventh phase of the product lifecycle – the product-testing phase – the following results were obtained (Fig. 8).

Figure 8 shows a reallocation of resources towards the use of labour in comparison with the theoretical estimates. At the same time there was a decrease in financial resources.

The comparison of theoretical (potential) and actual evaluations denotes the provision of knowledge generation development process for real production.

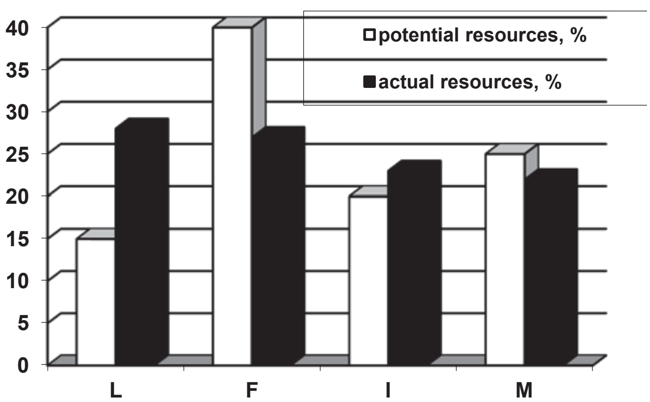

Figure 8: Allocation of knowledge generation resources during the product testing phase – potential and actual resources in %.

4.3 Directions for optimal use of resources

An analysis of the empirical data allows us to formulate the following direction for the optimisation of resource use at every stage of the product lifecycle.

Therefore, at the first stage of the lifecycle, when carrying out research and marketing analysis, it seems appropriate to examine the use of human and material resources with a view to reducing them. It can be assumed that it is preferable for a prior expert evaluation of the proportion of use of these resources to take place. In other words, it is possible that the solution to the problems of research and marketing analysis of the future product can also be developed with a smaller personnel structure and a lower equipment resource requirement.

During the second stage, when developing technical specifications and researching documentation, there must be a significant reduction in the proportion of material resources, perhaps by increasing the number of employees and improving the quality of staff. This is altogether feasible since we observed a significant reduction in the actual level of use of the labour force compared with the theoretical estimate.

During the third phase, of the development of electrical schemas and software, it is necessary to decrease the share of information resources – again due to the increase in staff numbers – as well as to improve the quality of personnel management. It should be noted that the three-fold difference between the theoretical estimates and the actual level of use of information resources locates the actual problem of optimising of information activities in the realisation of the third stage of the product lifecycle.

In the fourth phase of the product lifecycle, consisting of the development of design documentation, the impact of knowledge generation can boost a significant decline in the proportion of material resources, as well as result in a moderate increase in the use of information resources, the actual significance of which is well below the modelled level.

In developing the fifth phase – the technical documentation phase – it is expedient to reduce the proportion of financial and information resources. This is possible by increasing the degree of involvement of labour and material resources. In other words, there is a possibility to make financial savings through optimal reallocation efforts in the realisation of the fifth phase of the product lifecycle.

During the sixth phase of the lifecycle – the product manufacture phase – a slight decrease in the labour, financial and material resources by means of increasing the share of information resources will lead to an optimisation of the processes of knowledge generation.

Analysis of the distribution of resources at the seventh stage of product testing shows the need to reduce the proportion of the labour force along with a possible increase in financial resources. This is all the more possible because the actual level of use of manpower at this stage is almost twice the theoretical estimate of the contribution of labour in order to complete this phase of the product lifecycle.

The formulation of a direction for the optimal use of resources generated at each stage of the lifecycle provides an opportunity for savings and permits the most rational use of all kinds of resources.

5. Conclusion

The development of a new economic concept – the resource potential of the generation of knowledge as the totality of resources and capabilities of enterprises in the realisation of intellectual activity – has allowed the following theoretical and practical results to be obtained.

Firstly, a correspondence can be made between the product lifecycle and institutional support of intellectual activity in the generation of knowledge in the contemporary industrial enterprise.

Secondly, the proposed schematic and formalisation of the theoretical content of the resource potential of enterprise knowledge generation permits an evaluation of the capabilities of the enterprise in the realisation of intellectual activity.

Thirdly, on the basis of empirical research, the actual proportion of allocation of resources at every stage of the product lifecycle in the production of large enterprises of the Russian military-industrial complex can be determined.

A comparison of the theoretical and actual resource potential of knowledge generation allows a direction for the optimisation of resource use in the economy to be defined; effective resource management ensures the efficient development and manufacture of new products.

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