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Factors and Trends of Engineering Centers Development in the Network Structure of Innovations Reproduction

Vladimir Pastukhov[a], Nikolay Kliman[a] and Dmitry Alekseev[a]

[a]Russian Technology Agency, Moskow, RUSSIA

ABSTRACT

The article provides an overview of the concepts of "Engineering" and "Engineering Center" in the Russian and foreign literature; the author proposed the definition of "Industrial Engineering". It contains the brief historical excursion into the evolution of views on the engineering centers in the context of the network structure of the innovation economy; the basic methods of control over engineering centers; reproductive approach to engineering centers as an element of the innovation chain network economy system that allows us to consider the establishment of engineering centers as a form of investment. The authors also provide the information on the special role of high value-added services in the structure of the process engineering in a global competition for high-tech exports as well as the analysis of empirical data generated during the 2014-2016 from the engineering centers at the premises of the leading Russian universities, including a forecast of future trends.

KEYWORDS
Engineering, engineering center, reproductive approach, investment, technology, evolutionary approach

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Introduction

Russia is currently facing the tasks of modernizing the economy in order to propel it to the next level of development and master the fifth and sixth waves of innovation at a greater rate. All these processes take place in the key sphere of the economic system – in the sector of industry which should solve the tasks of import substitution in the conditions of technology import limitation. The stated challenges define a special topicality of the article, because the Russian engineering centers being commercially viable on the global scale are the links of the innovation chain without which it will be extremely difficult to solve the above mentioned tasks.

The demands of the market, the level of the science and technology development may provide opportunities of accelerated development for the

CORRESPONDENCE Vladimir Pastukhov ✉ s89055000550@gmail.com

companies having corresponding competences and knowledge, but at the same time make the outsiders out of the companies that do not have such competences. So, the article is about the engineering centres as the elements of innovation chains of global competitive power of the country.

Within the framework of this article the authors tried to deals with the following theoretical issues:

- to clarify the role of engineering centers in the economic theory and the theory of innovative development using the reproductive and evolutionary approaches;

- to show the role of industrial engineering in the networks structure of reproduction of innovations in the context of global development factors;

- to reveal the systemacity in development of engineering centers using reproductive approach;

- to reveal the factors and trends of development of engineering centers at the premises of the Russian educational institutions;

- to propose the authors' definition of "Industrial Engineering".

In the modern economic theory alongside with the labor, land and capital one designates entrepreneurship and information as the most important factors of production (Schleicher, 2006). According to K. Marx (2014) labor is a sole source of profit. In this regard in Marxism the factors are divided into the means of production and the workers' labor. The Austro-American economist J. Schumpeter (2007) in his book says that entrepreneurs are the main driving force of progress and development of economy, "But we call entrepreneurs (Unternehmer) the economic entities, the function of which is exactly realization of new combinations and which play the role of its active element" (Schumpeter, 2007). These two preconditions of different on the one hand, but on the other hand interconnected theories represent the basis of our study. The substantiation of this choice is the fact that the main capital of engineering centers are the people. It is difficult to imagine an engineering center of international standard (labor factor) without the engineers creating new constructions and technologies, without continuous process of improvement of the personnel's skills and knowledge. At the same time an engineering center as an element of innovation chain is an entrepreneurial structure and requires enough level of profitability for its own reproduction (entrepreneurial factor). In this regard we suppose it is relevant to consider an engineering center from the perspective of the synthesis of evolutionary economic theory of Schumpeter and reproductive approach of Marx which allows revealing the factors and trends of development of engineering centers created at the premises of universities in real time from the perspective of the modern economic theory.

Global Trends

K. Marx (2014) stated the factors contributing to the increase of labor productiveness, "Productive power of labor is defined by various circumstances, among them are an average degree of the worker's skill, the level of scientific development and the degree of its technological application, social combination of in the manufacturing process, sizes and efficiency of the production means as well as the natural conditions" (Marx, 2014). Notably, engineering center combines all the factors of high productiveness stated by Marx: high

qualification of the specialists, application of scientific discoveries for their integration with the purpose of creation of efficient, economically rational and ecologically friendly production facilities. It means that among the factors defining productiveness of labor there is an innovation element connected with the development of science – scientific researches aimed at solution of the technological problems.

Research of dynamics of the labor productiveness shows that the countries actively incorporating scientific achievements into the production have higher labor productiveness. Fig. 1 shows that self-reproducing system of innovation-driven economy of Germany is by 2.5 times higher than the Russian system. Besides, among the BRICS countries China outsteps Russia.

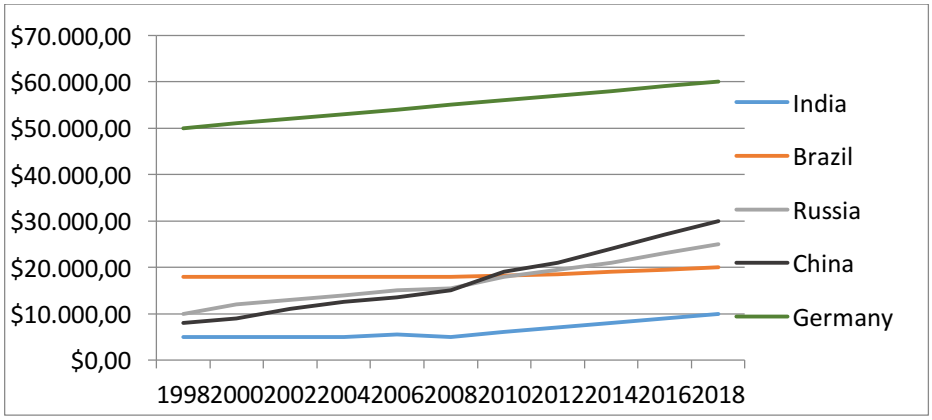

Figure 1. Labor Productiveness (GDP PPP per capita)

Analysis of global trends of labor productiveness, global index of innovativeness (table 1), jurisdictions of the largest engineering companies allows confirming interconnectedness of such categories as labor productiveness (technologies, labor, and worker), sensibility to innovations (table 1), level of income per capita and development of service sector (including engineering services) in industrialized and some developing countries. In this regard it is reasonable to use the systematic approach (Klejner, 2013; Bodrunov, 2014) towards the research of engineering centers, which will be developed in terms of synthesis of evolutionary and reproductive approaches.

The level of scientific development and its technological application is important, as it contains the initial point for innovations. Beginning from 2007 the INSEAD business school (France) in collaboration with the Cornell University and the World Intellectual Property Organization are conducting a global research of the innovative development of the countries (table 1).

Table 1. Global Index of Innovations 2015

National Economy	Rating (0-100)	Rank	Income
Switzerland	68.30	1	Large income
Great Britain	62.42	2	Large income
Sweden	62.40	3	Large income
Netherlands	61.58	4	Large income
USA	60.10	5	Large income

Finland	59.97	6	Large income
Singapore	59.36	7	Large income
Ireland	59.13	8	Large income
Luxembourg	59.02	9	Large income
Denmark	57.70	10	Large income
Hong Kong (China)	57.23	11	Large income
Germany	57.05	12	Large income
Iceland	57.02	13	Large income
Republic of Korea	56.26	14	Large income
New Zealand	55.92	15	Large income
Canada	55.73	16	Large income
Australia	55.22	17	Large income
Japan	53.97	19	Large income
China	47.47	29	Ordinary income
Russia	39.32	48	Large income
Belarus	38.23	53	Ordinary income
Brazil	34.95	70	Ordinary income
India	31.74	81	Ordinary income

Source: Global Innovation Index (2015)

Analyzing Rating 2015 we may conclude that there are three centers formed in the world which are capable of committing themselves to the role of a global innovative leader at transition to the economy based o knowledge; at the same time three regions are competing in the increment of innovative products (services) in the world goods turnover. There are the following countries among the leaders: North Europa alongside with Switzerland and the Netherlands. They are the most sensible to innovations and have a stable institutional environment. In the leader group there are also the Anglo-Saxon countries; the fifth position is occupied by the USA, the economy of which is the largest in the world by its nominal GDP. The third region is represented by Japan and three Asian countries, which were able to radically transfer "from the Third World to the First one" (Yew, 2016). Russia takes the 48th position in Rating 2015, which is comparable by the level with the BRICS countries. Despite a higher quality of the resource and human potential, Russia is behind China by the innovation index in the group of large, rapidly developing economies.

Comparison of the positions according to the global research of innovative development with the positions of the countries by their level of development both of the market of engineering services and the global companies targeting the market of engineering services (table 2) shows interconnections between the ratings investigating various aspects of development. In the countries with high labor productivity, which means, actively using high technologies in all the spheres of economy, the global index of innovativeness forming the environment for development of the international companies is higher (84 indicators are being analyzed). One of the most important events in the economy on the world market is the break-through of the sphere of services. The services of engineering (project) companies show stable annual increment rates, while the volume of the market according to some estimates (Knyaginin, 2013) may achieve $ 1.4 trillion per year by 2020, which is very impressive. In this regard let's consider the table of the largest international engineering companies for 2015 by the volume of the concluded (confirmed) engineering services contracts.

Table 2. Rating of the Largest International Engineering (Special-Purpose) Companies of 2015 by the Volume of their Engineering Services Contracts.

Company/ rating	Country	Web-Site	Main Services/Products	Sector
AECOM / 1st position	USA	http://www.aecom.com/	Engineering, procurement, construction, maintenance, project, management services	Engineering, design, construction, management
WorleyParsons / 2nd position	Australia	http://www.worleyparsons.com/Pages/Default.aspx	Construction, construction services	hydrocarbons sector into the power, infrastructure and environment, and minerals and metals sectors, oil and gas market, transport, power and energy, resources, water and social infrastructure sectors
ARCADIS NV / 3 position	Netherlands	https://www.arcadis.com/en/global/	Construction, construction services	Commercial developers, contractors, energy and natural resources, financial institutions, industrials, power, public sector, retail, transportation, water and utilities
Fugro NV / 4 position	Netherlands	http://www.fugro.com/	Engineering, procurement, Construction	geotechnical, survey, subsea and geosciences services. engineering design and large structure building projects
Jacobs / 5 position	USA	http://www.jacobs.com/	Oilfield products, systems and services	Aerospace & Technology; Buildings & Infrastructure; Industrial; and Petroleum & Chemicals
WSP|Parsons Brinckerhoff / 6 position	Canada	http://www.wsp-pb.com/	Measurement equipment and tools	Design, Engineering consulting, Environment consulting, Planning, Professional services
AMEC plc / 9 position	Great Britain	http://www.amecfw.com/	Engineering construction, project management	Engineering and project management
TECHNIP / 11 position	France	http://www.technip.com/en	construction	Project management, engineering and construction for the energy industry

Company/ rating	Country	Web-Site	Main Services/Products	Sector
SNC-Lavalin International Inc. / 12 position	Canada	http://www.snclavalin.com/en/	Engineering, construction and technical services	Engineering services, project management, construction, construction management, procurement and operations and maintenance
Tecnicas Reunidas / 15 position	Spain	http://www.tecnicasreunidas.es/en/	Professional and technical services	Design and construction of petrochemical facilities, power stations and industrial plants
Ramboll Group A/S / 21 position	Denmark	http://www.ramboll.com/		engineering consultancy, buildings, planning, urban design, transport, water
Hyundai Engineering Co. Ltd. / 26 position	South Korea	https://eng.hec.co.kr/		Engineering, construction
SWECO AB / 28 position	Sweden	http://www.sweco.se/		Engineering
Pöyry / 31 position	Finland	http://www.poyry.com/		Engineering and project management, management consulting, Management Consulting; Engineering Services;

Source: The 2015 Top 225 International Design Firms 1-100, Engineering News-Record (2015).

Application of the systematic approach to research of the engineering centers will help summarizing various trends of global development directly influencing the level of scientific development and the rates of its application in technologies. Engineering centers as an element of innovation chain of the world economy are the entrepreneurial structures implementing application of technological solutions in practice. The considered largest engineering companies have undergone a long way of development where the technological cooperation with the educational institutions plays an important role. That's why in Russia the projects of creation of engineering centers at the premises of the leading Russian universities able to solve the task of technological development have been implemented since 2013.

Review of the "Engineering" Definitions

Such terms as "Engineering", "Engineering Service" and "Engineering Center" appeared in our country relatively recently. In the Soviet period such activities were coordinated by the ministries with the industry-based R&D

establishments or/and design institutions at their premises, fitted with required equipment implementing the tasks in the mould of those implemented by the modern engineering centers.

Now we can state with assurance that the concept of engineering has been impacted into the scientific and business literature. Therewith there are construction, banking, financial, industrial and other forms of engineering. Each form has its own specifics, but we are mostly interested in industrial engineering. Analyzing the existing approaches we may propose our own succinct definition of industrial engineering.

With this purpose we are going to highlight the main approaches to the concept of "Engineering" in the Russian and foreign literature.

So, the general definition of engineering is "rendering engineering and consultative services of industrial, commercial and technological nature on the commercial basis" (Bljumin, 2013). The author of the definition does not state the direction of engineering, and what is the final purpose of service. The focus on organizational and managerial functions is defined in the universal business dictionary: "Engineering is engineering and consultative services, research, design-and-engineering as well as computational and analytical services, preparation of technical and economic substantiation (TES) of the projects, development of recommendations in the sphere of industrial management and control, and realization of production" (Lozovskij, Rajzberg & Ratnovskij, 1997). The UN Economic Commission for Europe, created for the purposes of economic development and fastening economic ties both on regional and international level, provides the following definition: "Engineering (Lat. ingenium – invention, knowledge, to create) is a set of activities connected with creation and exploitation of the infrastructure enterprises and subjects or a complex of design and practical works and services related to engineering and technical sphere and necessary for construction of a plant or its exploitation" (United Nations, 2010). The last definition is the most meaningful, though it is focused on infrastructural and construction objects of engineering, while we would like to focus on industrial engineering. Notably, The UN Economic Commission for Europe significantly contributed to the development of "The Guide for Drawing up International Contracts on Engineering" and "The Guide for Drawing up International Contracts on Consortium".

The focus directly on the production process is stated in the definition, provided by A.I. Borovkov (2012), Research Advisor of the Institute of Advanced Manufacturing Technologies: "Creation of complicated scientific products is a complex of scientific, design and construction as well as technological and industrial works known in literature as engineering".

Meanwhile, we can find a more complete definition in the category of "engineering services". For example: "services for preparation of the process of production and realization (works, services), preparation for construction and exploitation of industrial, infrastructure, agriculture and other objects, pre-design and design services (preparation of TES, elaboration of a design concept and other services of this kind)" (Dolgov, 2011). The definition developed under the preparation of the Manual on Statistics of International Trade in Services (UN) for the purposes of statistical research of international trade of services, reflects the specifics and the coverage of this scope best of all: "Engineering services is the engineering and consultative services at design, engineering

development and exploitation of the machinery (equipment), materials, devices, structures, processes and systems" (United Nations, 2010). There are four main directions of engineering services:

- engineering and technical design (of products, technological (production) processes, capital structures);

- engineering and technical consulting (not relating to certain projects of engineering and technical design);

- project management;

- additional services.

In the framework of our research we cannot be satisfied with the terms embracing all the sides of engineering. We need to reduce the concept to industrial engineering. In the Russian scientific literature there is no definition of industrial engineering except for the following one: "Industrial engineering is rendering services for creation and incorporation of industry (production facility, processing line, technology) on a turnkey basis, including development (conceptual) of the modernization project, project management, technological engineering and the elements of construction engineering" (Kesaev, 2014). Although it is not clear where lies the difference between the latter definition with underlining construction direction and those definitions of the Russian and foreign authors considered before. In 2016 National Research University - Higher School of Economics on commission from Ministry of Industry and Trade of the Russian Federation realized a relevant research with the purpose of formation of the complex monitoring system including the system of statistical recording of indicators of development of the engineering services market and industrial design in Russia for creation of the information background ensuring support of the government policy in the specified field. The research contains the following definition of industrial design: "Industrial design is the activities implemented without subcontracting or by contract with the third party for development and change of the form, exterior or consumer properties of the industrially manufactured products" (Methodology of Statistic Monitoring of Engineering Services and Industrial Design, 2016). Development of engineering centers at the premises of universities is based on the specialization, i.e. on the work in a certain area. For example: electronic and radioelectronic industry (Moscow Engineering Physics Institute), rear-earth metals (Moscow Institute of Steel and Alloys), laser and additive technologies (Ural Federal University, Vladimir State University), composites (The Bauman Moscow State Technical University, Kazan Aviation Institute), tool-making industry (Moscow State Technological University "Stankin"), chemical industry (Kazan State Technical University), Oil and Gas Industry (Moscow Institute of Physics and Technology, National Research Irkutsk State Technical University) etc. Due to existence of various forms of engineering (financial, construction etc.), we consider it possible to introduce into the scientific circulation the author's definition of industrial engineering, taking into account the approach of the United Nations Organization, characteristics of engineering, introduced by A.I. Borovkov (2012) and practical recommendations of O.A. Saprykin (2008), Chief Engineer of the Space Regatta Consortium. Industrial engineering is the activities on continuous process of research, design and realization of a complicated scientific product/structure, designed for updating of scientific discoveries to the stage of technological mock-ups, operating devices, confirming the efficiency of the

applied novelties and representing a real practical interest for commercial exploitation.

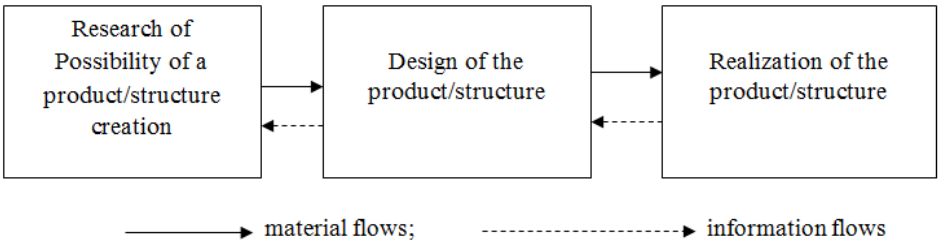

Figure 2. Main Stages of Modern Engineering (Kimel'fel'd, 2015).

The stages of the modern engineering represented at figure 2 comply with the functions of engineering, described by Professor D.V. Rybec (2011), exactly:

"- Researches. Application of mathematical and general scientific methods, means and concepts, experiments and other tools for initial research of the problematics, search of new principles and processes.

- Development. Application of the research results to the practical goals, creative use of the knowledge for creation of new models in various fields, technological processes, industrial facilities and enterprises in general.

- Design. Design of the process of a production or production system creation, definition of the applied materials, characteristics and the structure of the production or system, assurance of the compliance with the requirements and satisfaction of needs and expectations.

- Definition of price and financial indicators of the project. This function implies development of the budgets and costing of the project, preparation and conduction of tenders, creation of new financial instruments and schemes.

- Organization of Production. Defining the plan of placement of the production processes, choice and acquisition of necessary equipment, raw materials, materials and components necessary for production as well as the sources and their supply, integration of all the production processes, inspecting, testing, pre-commissioning, training of the personnel and organization of production".

Modern model of control over engineering processes accepted in developed countries significantly differs from the Russian practice. Abroad it is an accepted practice when a contractor is occupied by all the processes on research and design to the full extent as well as realization. In this case the majority of the risks are taken by the В этом случае большую часть рисков на себя берет EPC-contractor (fig. 3), thus releasing the customer from the functions which are not peculiar to it.

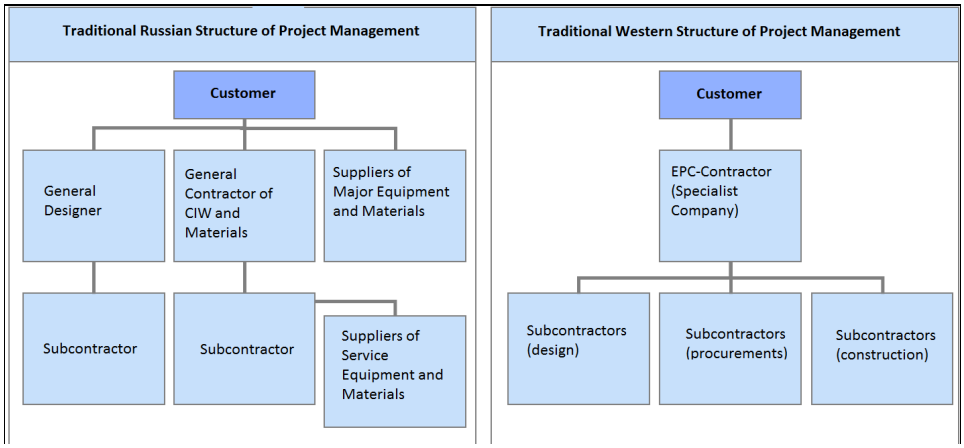

Figure 3. The Models of Engineering Projects Management in the Russian Federation and Western Countries (Os'makova & Pastuhova, 2015).

Figure 3 shows the main stages of modern engineering and its main functions which in the Western structure of project management are concentrated in the specialist company – EPC (M) contractor, independently cooperating with the projects of management entities (construction engineers, suppliers, designers etc.).

Reproductive Approach to Industrial Engineering

The novelty of our article is in the application of the reproductive approach to development of industrial engineering in Russia. Reproductive approach (Alekseev, 2016) allows, on one hand, connecting quality characteristics of the research object, and, on the other hand, the results of the empirical analysis of the new created engineering centers at the premises of universities.

The deliberate policy of the government on modernization of economy contributes to development of industrial engineering. Development of the latter is directly accompanied by incorporation of innovations, which means directly contributes to modernization of industry. One of the strategies (Nikitin, 2016; Zagashvili, 2016) of modernization is import substitution, which is especially important for high-technological branches and science-driven industries. The best definition of import substitution close to real practice is considered in the scientific paper by A.V. Danilov-Danilyan (2016): "Import substitution is a process of displacement of import goods and services from the national market through increase in realization of the same or analogical goods and services of the national production" therewith speaking about "Creation of brand new branches and kinds of entrepreneurial activities is also import substitution, though of a proactive nature, decreasing dependency on import in future, i.e. a kind of 'import-outrunning'". It is impossible to implement such a complicated task separately, and it requires technological cooperation; participation of the government will be also beneficial. Thus, interconnected chains including such links as business, universities, research centers and government, form the environment for establishment of industrial engineering.

In the world practice the universities become a key link of the innovation system, where the competence of the future specialists is being formed. However

it is impossible to gain success without cooperation of educational institutions with the industry sector. It requires technological cooperation, so, there is a need in the theory considering all the participants of the project integrally. It is realizable by using the methodology of the reproductive approach which will be applied by us further. It connects creation and development of industrial engineering as a system, an integral process of innovative financing, further incorporation into the production and subsequent implementation of services. It is the circulation of capital in the framework of industrial engineering. We will show the transformation of capital from financial into industrial and further to the form of a service (product). Indeed, in practice we can see that the high technology business as an entity embraces three stages – capital formation, manufacturing of products and circulation of a service on the market, which is yet more proof of the unity of circulation of industrial capital, which means the unity of capital as part of industrial engineering.

In the governmental policy pursued by the Ministry of Industry and Trade of the Russian Federation these processes are considered and the corresponding instruments of industrial policy are being formed. So, the team of D. Manturov, G. Nikitin & V. Os'makov (2016), the Minister of Industry and Trade prepared the lists of the potential projects, and at "formation of the strategic planning it is proposed to use a product-based approach", notable for its fastness, constant upgrading and verification.

Formation of Capital (1st stage). The government is motivated in support, creation and development of technical universities towards technological cooperation with real economy. Due to almost complete lack of engineering centers in the universities, the task of development is taken by the government, de facto acting as a qualified investor (Lejn, 2010). As known, an investor requires return on the advanced capital and the government is ready to invest provided that: "a specialized engineering company is created, being a separate legal entity rendering engineering services to real economy. The legal entity is created with the participation of the university and the industrial partners" (Development of Engineering Centers at the Premises of Universities. Collection of Researches, 2015). Thus, the engineering centers considered by us, are an innovation business integrated into a university, exacter into its environment. According to Development of Engineering Centers at the Premises of Universities (2015). "Engineering centers at the premises of universities are at the same time the business units of these universities and independent commercial organizations leading its economy in the sphere of engineering". All the above said allows concluding that there are all the grounds for analyzing engineering companies created by the government (or under its support) as the investments, calculating the parameters and pay-back periods through tax liabilities.

Investments into the industrial engineering are realized through subsidies for enlargement of the state commission of the institution, taking the form of capital costs, i.e. the investments connected with the following factors:

a) cooperation of educational activities (purchase of equipment, software, investments into training, refresher course and advanced professional training). These investments are important in regard with the rise of capital endowment which first of all influences the labor productiveness (Fig. 1. Labor productiveness (GDP PPP per capita);

b) recruiting of skilled professionals having (of capable of acquiring) the required competences (expenses for salary fund with social security contributions);

c) capital investments into industrial engineering (purchase of equipment, acquisition of intangible assets etc.);

d) creation of joint projects, new commercial organizations, engineering centers (attraction of private investments into the projects).

There are the following volumes of investments at the stage of the capital formation:

- 2013 – 12 projects received 1 245.1 million RUR
- 2014 – 9 projects received 604.9 million RUR
- 2015 – 10 projects received 390.0 million RUR

The total amount of the governmental investments is equal to 2 240.0 million RUR.

Reproduction of Services (2nd stage). After sufficient capital investments the financial capital turns into the production capital. Reproduction of intellectual services of the industrial engineering centers may take a simple form (permanent scale), or an expanded form (which any organization strives for, looking to development). The direct process of reproduction takes the form of jointly performed works within the framework of contracts (subcontracts).

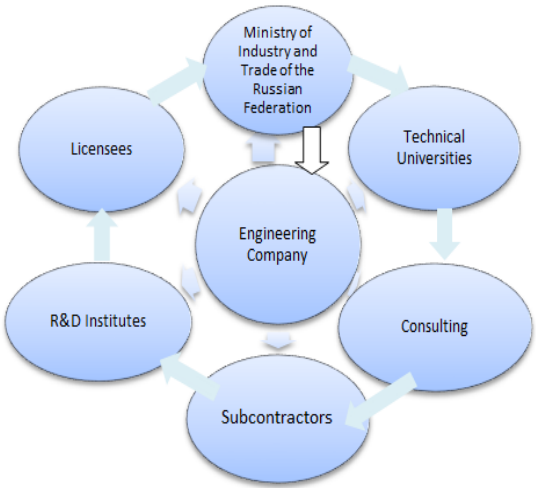

Figure 4. Continuous Circulation of Reproduction of an Engineering Center

The production circulation being the core creating high added value of the services reproduction (2nd stage) in the network structure of economy partially forms the demand for innovative services by itself through popularization of the demand, which means through translation of the developed technologies (work with the governmental authorities, participation in exhibitions and publications). Here we should note that high added value of the industrial engineering services is only created on the 2nd reproduction stage.

The government requires scientifically applied competences of the personnel, while the Russian economy requires acknowledged specialists in the sphere of industrial engineering. In the continuous circulation of reproduction of

an engineering center (fig. 4) there is a conventional circulation of the services reproduction (2nd stage). Engineering company created with the participation of government at the premises of the university generates brand new ideas and developments. After finding the customer for potential industrial sample, technological mock-up or operating devices confirming the efficiency of the applied novelties, the parties sing up the contracts, involve the subcontracts, consulting companies, and research organizations. The most promising management model in the West is EPC (M) (fig. 5).

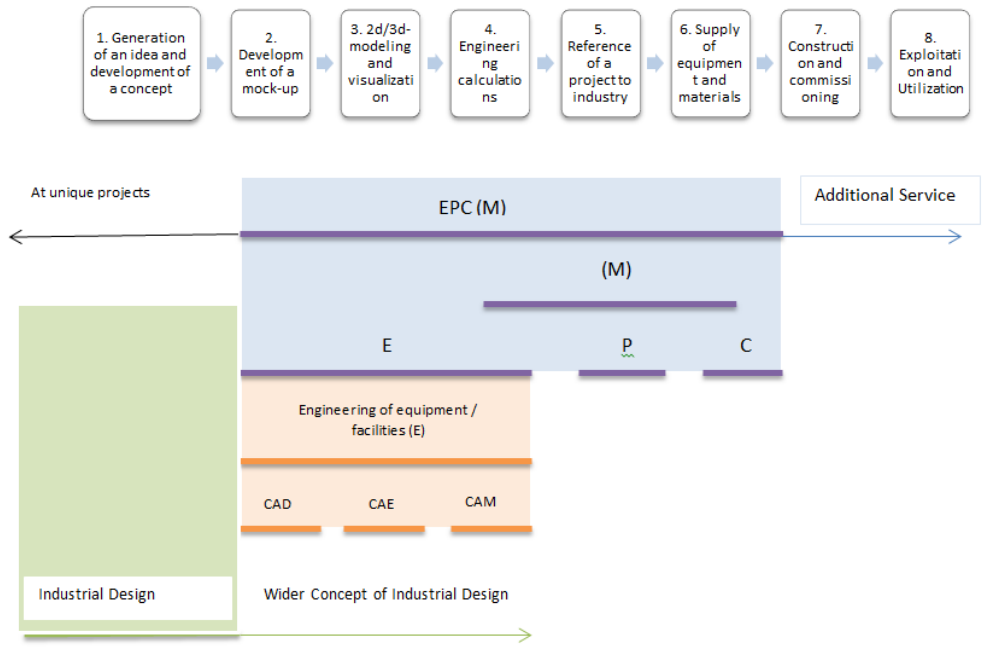

Figure 5. Role and Place of EPC (M) – Contractor in the Product Lifecycle (Os'makova & Pastuhova, 2015)

As we noted in the beginning the driving force of the progress according to J. Schumpeter is an entrepreneur: "He stands between those who is willing to implement new combinations (customers – D.A.) and the owners of the production means (investor – D.A.)" (Shumpeter, 2007). And our approach allows showing that governmental investments having begun its flow in the form of monetary funds, have taken the industrial, entrepreneurial form in the process of reproduction. Engineering companies, integrated into universities are managed as entrepreneurial companies, forming the stock of innovation orders from private and public customer and striving for the maximum revenue.

Realization of Goods and Services (3rd stage). As the reproduction of a service achieves its goal, and is consumed by the customer, the 2nd stage turns to the consumption of the created goods, or in other words the sale takes place. Actually no added value is created at the 3rd stage (the stage of circulation of services and goods), though it may look exactly this way. High added value has already been created at the 2nd reproduction stage. The 3rd stage is the stage of creating not the value but the extra charges and the final contract accounting takes place. In this regard the attention of the government, business and the

research society should first of all be turned to the process of engineering services reproduction itself (2nd stage).

According to the data Development of Engineering Centers at the Premises of Universities, (2015): "Total volume of the engineering services rendered by engineering centers at the premises of universities in 2015 exceeds 1.6 billion RUR".

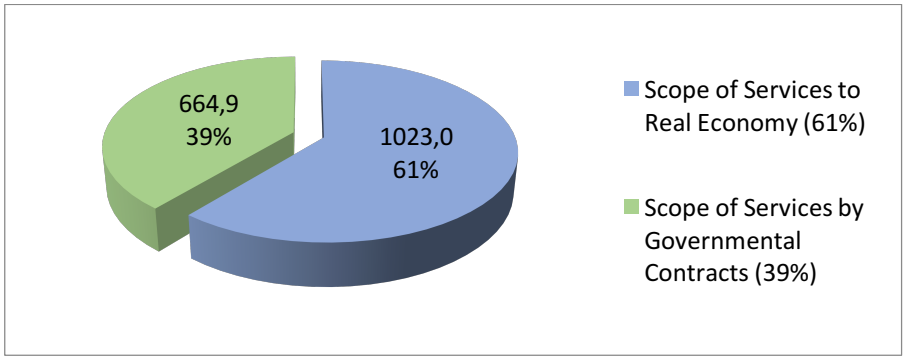

Figure 6. Structure of a stock of orders of engineering centers in 2015 in section of the customers by the contracts concluded, million RUR (Development of Engineering Centers at the Premises of Universities, 2015)

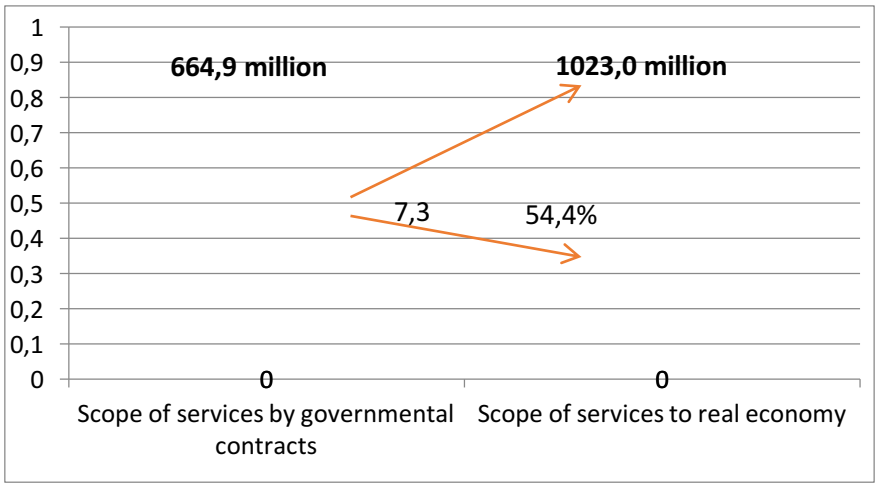

Figure 7. Structure of the stock of orders of engineering centers in 2015 in section of the customers by the contracts concluded in 2015, million RUR (Development of Engineering Centers at the Premises of Universities, 2015)

The last data (fig. 6 and fig. 7) allows concluding that government investment into the development of industrial engineering centers at the premises of the Russian universities provide the background for economic modernization already at the initial stage of implementation. Total volume of investments for 3 years from 2013 till 2015 equal to 2 240.0 million RUR, in 2015 only provided the revenue of 1 687.9 million RUR from private and public contracts which allows concluding that the used form of support in rather efficient.

Conclusion

Development of engineering centers at the premises of technical universities is a driving force to the development of high technologies both at national and at international scale. The response to the aggression of the foreign countries policy is development of the import substitution strategy which is tightly connected with modernization. The key part of the common import substitution strategy is creation of globally competitive Russian engineering centers, being the links of the innovative system of the Russian economy.

The interconnected chains shown by the authors including such links as business, universities, research centers and government form the environment for establishment of industrial engineering and it is only the systemic approach that is able to provide adequate responses to the set challenges. The most promising approaches, in our opinion, are the synthesis of reproductive and evolutionary approaches. Not seeking to embrace all the aspects we clarified the role of engineering centers in the economic theory and showed the role of industrial engineering in the network structure of reproduction of the innovations.

In the framework of this article we propose the author's concept of "Industrial Engineering" which can be used both in the development of theoretic economy and in the practice of building a modern network of engineering centers at the premises of universities.

Based on the data, on the one hand, about federal subsidies for opening of engineering centers at the premises of the Russian universities, and, on the other hand, on the data on the engineering centers' stock of orders, we may expect sustainable development of this innovative chain of the Russian innovation system.

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Notes on contributors

Vladimir Pastukhov, PhD, General director of the Russian Technology Agency, Moscow, Russia.

Nikolay Kliman, PhD, Deputy general director of the Russian Technology Agency, Moscow, Russia.

Dmitry Alekseev, Leading specialist, of the Russian Technology Agency, Moscow, Russia.

References

Alekseev, D.S. (2016). Venture Capital: Real and Artificial. *Problems of modern economy, 3,* 59-63.

Bljumin, A.M. (2013). *Information Consulting: Theory and Practice of Consulting*. Moscow: Dashkov i K.

Bodrunov, S.D. (2014). Russian Economic System: the Future of High-Technological Material Production. *Economic questions, 2(40),* 5-16.

Borovkov, A.I. (2012). *Computer Engineering*. St.Peterburg: Polit. Univer. Publ.

Danilov-Danil'jan, A.V. (2016). The Process of Import Substitution in the Russian Economy: Peculiarities and Myths. *Bulletin of the Institute of Economics of the Russian Academy of Sciences, 3,* 21-31.

Development of Engineering Centers at the Premises of Universities. (2015). *Collection of Researches*. Moscow: Higher School of Economics.

Dolgov, S.I. (2011). *Encyclopedia of Foreign Trade*. Moscow: Economy.

Global Innovation Index. (2015). *Cornell University, INSEAD and WIPO*. Direct access: http://www.wipo.int/portal/en/

Kesaev, S.A. (2014). Classification of Engineering. *University Herald, 14,* 147-151.

Kimel'fel'd, R.V. (2015). Modern Engineering in the Sphere of Scientific-Driven Production: Grounds, Methods and Perspectives of Development. *Bulletin of Moscow State Open University. Series: Economy, 4*, 87-92

Klejner, G.B. (2013). System Economic as a Platform for Development of the Modern Economic Theory. *Economic questions, 6*, 4-28.

Knyaginin, V.N. (2013). *Potential of Russia on the Global Market of Engineering Services*. Direct access: http://www.csr-nw.ru/files/csr/file_category_1274.pdf

Lejn, D. (2010). Russian Transformation: Is It the Formation of the World Nation? *World of Russia: sociology, ethnology, 4,* 3-24

Lozovskij, L.Sh., Rajzberg, B.A. & Ratnovskij, A.A. (1997). *Universal Business Dictionary*. Moscow: Infra-M.

Manturov, D., Nikitin, G. & Os'makov, V. (2016). Planning of Import Substitution in the Russian Industry: Practice of the Russian Governmental Management. *Economic questions, 9,* 40-49

Marx, K. (2014). *Capital. And Critique of Political Economy*. Moscow: Mann, Ivanov i Ferber.

Methodology of Statistic Monitoring of Engineering Services and Industrial Design. (2016). Direct access: http://engpromdesign.ru/documents/23984/#

Nikitin, G.S. (2016). Key Tools of the New Industrial Policy of the Russian Federation. *Effective crisis management, 1*, 74-79.

Os'makova, V.S. & Pastuhova, V.A. (2015). *Engineering and Industrial Design*. Moscow: Onebook.

Rybec, D.V. (2011). Engineering and Consulting Services on the International Market. *Russian foreign trade bulletin, 8*, 84-95.

Saprykin, O.A. (2008). Engineering in Russia: New Perspective. *Innovations, 3,* 28-32.

Schleicher, A. (2006). *The Economics of Knowledge: Why Education is Key for Europe's Success. Lisbon Council Policy Brief*. Direct access: http://www.oecd.org/education/skills-beyond-school/36278531.pdf.

Shumpeter, J. (2007). *Theory of Economic Development. Capitalism, Socialism and Democracy*. Moscow: Jeksmo.

The 2015 Top 225 International Design Firms 1-100. (2015). Direct access: http://www.enr.com/toplists/2015_Top_225_International_Design_Firms1

United Nations (2010). *Manual on Statistics of International Trade in Services 2010*. Direct access: http://unstats.un.org/unsd/publication/Seriesm/seriesM_86Rev1e.pdf

Yew, L.K. (2016). *From Third World to First. Views and Believes of Lee Kuan Yew*. Moscow: Mann, Ivanov i Ferber.

Zagashvili, V. (2016). Foreign Experience of Import Substitution and Possible Challenges for Russia. *Issues of Economy, 8*, 137-148