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TECHNOPARKS AND SCIENCE-INTENSIVE PRODUCTION: AN ADVANCED EXPERIENCE*

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Abstract. The development of science-intensive technologies is crucial for the social and economic stability of the nation. The current technological system calls for a unification of scientific and technological approaches in the innovation-driven development. The introduction of innovations is necessary for modernization of the national economy and for making Russian companies more efficient. Without the constant development of science and education, there is a threat of social and cultural stagnation; while the world trend of changing and improving the production involves the emergence of new formats of economic interaction in which the science-intensive and convergent technologies play the key role. The science-intensive development requires the full-fledged institutional interaction, the joint activity of stakeholders, i.e. the development of special territories where economic, infrastructural and social-cultural conditions allow the introduction of new technologies. Technoparks represent one of the most popular formats of such territories. Today the Russian Federation has several technoparks. However, their work is not always satisfactory and needs optimization, especially for the greater efficiency of the science-intensive technologies. To identify the most effective ways of upgrading the Russian technoparks, the authors studied the experience of 12 most successful technoparks abroad, and make recommendations for improving the management system of technoparks and enhancing their scientific and innovative activities. The article describes the features of science-intensive technologies; the challenges the innovative organizations face; the role of technoparks in ensuring the growth of the innovative potential of the state; the formats and structure of technoparks as well as the recommendations for making them more effective in developing science-intensive technologies. The article also presents the results of the studies of the Russian technoparks over the last ten years. The authors try to identify the main methods for optimization and modernization of technoparks to increase their role in the innovation-driven development of the state.

Key words: technoparks; science-intensive technologies; NBIC-convergence; innovations; business incubators; national innovative strategy

The development of new technologies is a diverse and multi-directional process, which makes them difficult to study. The participants in the 2016 *Consumer Electronics Show* (hereinafter CES) noted the lack of truly groundbreaking solutions in the technologies presented by the leading world producers [34]. The experts were critical about the results of the show and mentioned the stagnation in the sphere of innovative solutions. The reaction to CES 2017 [35], despite the similar situation with the products

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on display, was more optimistic: the majority of experts agreed that the producers still developed new technologies, but changed the vector of their activities. Thus, one innovative cycle ended and the next one began, which altered the public perception of innovations. A year ago, the experts were skeptical due to the slowdown of the development of consumer technologies, today they consider the same process as the start of a new wave of developments. This example shows that the task of introducing a universal methodology for assessing the innovative development is complex and a long way away from a satisfactory solution.

Moreover, the term *innovation* is multi-faceted and can be defined as: a new object [14], idea [27], technology, function [29], method of organization or action [18], managerial solution [1], implementation of a new idea, marketing a new product, change of the social environment [24], form of communications [30], a knowledge-building process [21], a new standard, the creation and introduction of a new object, etc. Today qualitative rather than quantitative characteristics of innovations become more important. In the field of consumer technologies, the quality means the possibility of the user's technological solution interaction with other technologies or devices used by him and people around him; user-friendliness, degree of protection, self-learning capacity, etc. In the fundamental research, it is more difficult to identify specific directions of development, but one can identify the need to combine activities of different sciences and for more effective interaction with social and economic systems that influence the innovative development. Consumer and fundamental innovations are interconnected, thus, considering the impact of social-cultural and economic factors on innovations, one can say that innovative processes are to be studied in terms of institutional interaction.

Theoretical models and applied research of the innovative processes often rely on the 'collateral' aspects, such as the efficiency of the auxiliary personnel engaged in the production of new technologies (not the developers, but financiers, suppliers, public relations managers, etc. involved in the project), bureaucratic barriers, legal and normative acts (in the international projects) and so on. 'Collateral' aspects are often as important as the technology and knowledge [7]. They usually depend on the degree of diffusion of new technologies in the economic, social-cultural and/or legal spheres of life. The researchers as a rule distinguish *economic* and *social diffusion.* The economic diffusion indicates the possibility of introducing new technology in the production sphere, financial sector, markets and consumer sphere. The social diffusion is the degree to which new technology penetrates in the social-cultural environment and social relations.

Russia's current position in the International Innovative Activity Rating is not high [11]. However, in assessing a country's innovative activities and potential, in addition to the ratings (which is an aggregated indicator) one has to look at the absolute numbers as well. For example, in 1981 there were about 110,000 applications for patents (1), while in 2015, the Rospatent accepted 45,500 applications for registration of inventions, and more than 16,000 of them were filled out by foreigners (2); the majority of patents registered not the new technologies developed in our country, but the already existing innovations the foreign organizations produce in Russia. In other words, *thrice less inventions* were made in contemporary Russia than in the RSFSR. And it is not the finished product that is registered but *an application,* i.e. an attempt to register an intellectual property object that can become a product [23]. That is why one of our coun-

try's priority tasks in the coming years is building up a high-technology potential and breaking into the leading international technological markets dominated by the science-intensive and converging technologies (including NBIC) [26].

The investments in new developments in the Russian Federation in conventional measures is comparable to those in the countries with a high rate of new technologies [32]; thus, there are institutional problems in the system of managing science-intensive technologies at every stage in their development and diffusion. These problems cannot be regarded as a derivative of the 'transition period', a consequence of economic problems, an impact of sanctions, etc., because this situation has prevailed for over a quarter of the century, while the innovative stagnation does not slow down despite the efforts of the state and society. Thus, development of the country's technological potential is not only a problem for the science, education, government, etc., but also a symptom of global flaws in the interaction of social institutions. To solve this problem we need a comprehensive and systemic approach to the analysis of institutional processes.

INNOVATIVE DEVELOPMENT UNDER THE CONTEMPORARY CONDITIONS

The nowadays innovation trends (both in fundamental and consumer fields) are closely linked with convergence. All sophisticated technologies hinge on interaction with other technologies, which requires a high level of cooperation and trust between developers, investors, supervisory bodies, markets, consumers and society as a whole. The relations between business and science organizations are of a particular importance for many private companies have already made great strides in creating innovative products and services. The innovative science-intensive technologies are costly and require time with a relatively low chance of returning the investments and making a profit. Though innovative products yield significant advantages for an organization, the development and introduction of the novelty, on the contrary, makes the company's social-economic system less stable and increases risks. There are several reasons for that: analytical instruments cannot provide reliable forecasts of the payback of a new technology; it is not always clear to what extent an organization is ready to produce or introduce innovations; there are problems with innovation diffusion; the consumer may react to a new product/service in an unexpected way; the competition may use some experience of the innovative company practically for free.

The following factors are key for the innovative development: infrastructure characteristics; communication between stakeholders; social-cultural aspects of interaction. These factors, as well as the attributes of the contemporary technological system (3) [17] and social-economic relations, require to develop areas where the infrastructure, communications and cultural interaction ensure an effective process of developing new forms of products, services and business, such as *technoparks.* The model of technopark was introduced about 60 years ago at Stanford University. Under *Frederick Terman's* guidance the university leased some of its land to high-tech companies interested in buying and using the university's intellectual developments and in bringing undergraduates and graduates into the project. The main feature of this approach was the requirement of commercial profitability. The model provided a prototype for many high-tech companies (4) and later formed the basis of the *Sylicon Valley* technological center [16].

Subsequently the industrial parks were created in Europe (France, Belgium, etc. in the 1970s) [33], North and South America, Asia, Australia (Canada, Brazil, Singapore, Malaysia, India, Japan, etc. in the 1980s and 1990s) [10; 22] as well as in the former Soviet Union (Russia, Belorussia, Uzbekistan, Ukraine, etc. in the 1990s—2000s) [4; 12; 15]. Today there are more than 1000 industrial parks across the world, up to 60% of them are in the USA (more than 30%) and Europe (more than 30%); they rapidly develop in Asia and South America. According to the international experience, it takes at least 10 years to launch a fully-fledged industrial park and 20—40 years to gain international recognition [20. P. 20; 28].

THE STRUCTURE AND FUNCTIONS OF THE TECHNOPARK

To identify the types of technoparks one must have a clear idea of their purpose. Though the scientific definitions of the term 'technopark' are similar, the interpretations of their mission vary. For example, a technopark connected with the production can be called 'an industrial park', connected with the entrepreneurship — 'a business incubator', with science — 'a science city' or 'a research park'. Without going into terminological issues, let us proceed from the broad meaning of the technopark (including all other meanings) and identify two main approaches to the mission of technoparks. According to the first approach, a technopark is an organization aimed at developing innovative technologies. Commercialization of developments is welcome, but in establishing a new technopark innovations, innovative characteristics, engagement in research and development (R&D) are the key features. According to the other approach, the main aim of technoparks is to boost competitive advantages and business efficiency through science-intensive, converging and innovative technologies. This is the ideology of the International Association of Science Parks (5). Today two types of technoparks are sometimes combined, for example, technoparks incorporate business incubators to develop small innovative enterprises (hereinafter SIEs), which makes them more viable [5] (6).

We believe that the classification of technoparks by the 'science for business' or 'business for science' principle is necessary, so we identify the following types of technoparks: created as regional development instruments; to speed up the development of an economic cluster; to develop science-intensive, converging and innovative technologies. The activities of most technoparks involve the state, so the mission and aims of technoparks depend to a large extent on the national innovation strategy of the host state. The analysis of the peculiarities of national innovation strategies together with the aims of technoparks reveals the following trends: the strategy of accumulating experience to study and use the entire range of technologies, cases, mechanisms and instruments available on the international markets before creating a new unique technological system; the strategy of copying the best technologies — the most successful technological solutions are copied, the production according to these technologies is launched as quickly as possible; the strategy of building up and developing unique technologies with the minimum use of international experience. These strategies are not mutually exclusive for they represent the main trends in the development of innovations at the state level.

The formation of the system of interaction with stakeholders is an important aspect of technoparks' activities. Usually the main stakeholders of a technopark are [2]: science and research centers; universities and government agencies; investors and clients; international partners and suppliers; business and production; professional associations and non-governmental organizations, etc. The majority of technoparks cooperate with universities [31], but some do not forge durable links with the higher education institutions.

Once the mission, goals, communications with the stakeholders as well as the production and business processes are set, it is possible to form the structure of a technopark that consists of two main areas: production and services [3; 8]. *The production structure includes*: production space and workshops; office space; test areas; lab complexes, computer and analytical resources and data centers; conference rooms, press centers and premises for various events; internet resources, portals, etc. *The service structure includes:* consulting structures; financial and credit systems; information system; marketing and advertising system; head-hunting and human resource development system; logistical center; storage facilities; technical services and life-support system, etc. Such an approach to the structure of technoparks is theoretical-descriptive rather than practical because technoparks can modernize and change their systems. The technopark format depends on a number of factors, so a comprehensive analysis would use the following criteria that define a technopark's structure: territory format; the size of space and premises; the number of enterprises; property structure; management system; technopark architecture;the criteria for admitting residents; availability of services, etc.

Technoparks have been working in the Russian Federation for about 25 years (7). They gave a boost to the development of some new technologies, but their activities do not always yield the desired results. There are studies seeking an answer to the question why these technoparks are not effective enough, but for the most part these studies assess the impact of technoparks on the regional economy or economic indicators. Though accepting the importance of these criteria let us note that in addition to the commercial results the scientific research function of technoparks is highly important. However many Russian technoparks turned into office centers and the activities of many companies within the technoparks are far from the creation of science-intensive technologies. This approach is effective as an instrument of assisting business, but the technopark model implies its use as a mechanism for enhancing innovative activities and for commercialization of R&D and not the development of business as such. Therefore, the activities of today's Russian technoparks need to be optimized with the focus on developing science-intensive technologies. Considering the urgent need to develop science-intensive and converging technologies in the Russian Federation and the growing practice of creating technoparks as mechanisms for innovative development and commercialization of R&D results, the improving management of technoparks at the organization, sectoral and institutional levels must become a priority. We analyzed the success stories of some international technoparks to identify for the most effective models of technopark activities and to offer recommendations for improving them.

TECHNOPARKS ACTIVITIES

We analyzed 12 organization in different countries to identify the key activities of today's technoparks. The technoparks selected for the analysis differ widely in terms of their activities, purposes, territories, managements and other features (see Table 1) [6; 13; 20].

Table 1

Features of the technoparks

Technopark	Characteristics
1. **Research Triangle** (*USA*)	**Founded in:** 1959
	Area: 2800 hectares (premises — 6,700,000 m^2)
	Number of employees: more than 52,000
	Number of organizations: more than 170
	Work with universities: active cooperation
	Admission criteria: organizations engaged in R&D (8) and production for experimental purposes; environment-friendly production
	Services: a wide range of outsource services and preferential lease rates
	Area of activity: the core activity is research in biological, medical and pharmaceutical technologies
	State participation: support
2. **Silicon Valley** (*USA*)	**Founded in:** started to work as a free zone in the 1950s—1960s
	Area: 2800 hectares (premises — 6,700,000 m^2)
	Number of employees: more than 250,000
	Number of organizations: more than 100
	Work with universities: active cooperation
	Services: residents can use a simplified taxation system and business preferences
	Area of activity: production and IT research
	State participation: government does not take part in running the technopark, but is a client of resident companies
3. **Lahti Science and Business Park** (*Finland*)	**Founded in:** 2008
	Area: 70 hectares (premises — 13,000 m^2)
	Number of organizations: more than 50
	Work with universities: universities take part in research activities and commercialization of technologies
	Admission criteria: preference to forestry companies that contribute to the social-economic development of the region
	Services: has a business incubator, offers preferential tariffs and a flexible rent payment
	Area of activity: information and communication technologies, biological, pharmaceutical and medical development and alternative energy sources; was established for developing the region, but ended up as a science center
	State participation: managing companies are limited liability companies with city municipalities holding the controlling stake
4. **Lakeside Science and Technology Park** *(Austria)*	**Founded in:** 2002
	Area: 22 hectares (premises — 28,000 m^2)
	Number of employees: more than 400
	Number of organization: 52 (of which 20 startups)
	Work with universities: universities play an auxiliary role and act as partners
	Admission criteria: IT companies
	Services: has business incubators, but does not offer extensive outsourcing services; prefers startups
	Area fo activity: IT
	Government participation: is partly owned by the state and private organizations
5. **Otaniemi** (*Finland*)	**Founded in:** 1949
	Area: 200 hectares (premises — 40,000 m^2)
	Number of organizations: more than 800
	Work with universities: universities take part in research procedures
	Admission criteria: prefers companies in forestry
	Services: has a business incubator, offers preferential tariffs and a flexible rent paying
	Area of activity: electronics, alternative energy, environmental protection, forestry
	Government participation: is administered by government agencies and private organizations

Table 1 Continuation

Technopark	Characteristics
6. **Software-park Hagenberg** (*Austria)*	**Founded in:** 1990
	Area: 200,000 m^2 (premises — 15,200 m^2)
	Number of employees: more than 250
	Number of organizations: more than 50
	Work with universities: universities provide specialists and take part in joint research
	Admission criteria: IT
	Services: has two business incubators and offers a range of services (outsourcing) and a flexible rent paying
	Area of activity: software development and IT
	Government participation: is owned by a private developer company in which the government holds a stake
7. **Sophia-Antipolis Park** (*France*)	**Founded in:** 1969
	Area: 2400 hectares (premises — 1,100,000 m^2)
	Number of employees: more than 40,000
	Number of organizations: more than 250
	Work with universities: initially there was no university, but now it has extensive cooperation with the Nice University
	Admission criteria: companies that benefit the region and have environment-friendly production
	Services: has a business incubator and offers a wide range of services on the basis of outsourcing
	Area of activity: social-economic development and diversification of the region towards biological, pharmaceutical and medical R&D as well as communication technologies and chemical research
	Government participation: part of the complex is privately owned (created by a person, but later supported by the government) and aimed at developing a property cluster; is managed by a state company, with some organizations engaged in development and commercialization
8. **Technologiepark Heidelberg GmbH** (*Germany*)	**Founded in:** 1984
	Area: 5 hectares (premises — 50,000 m^2)
	Number of employees: more than 1400
	Number of organizations: more than 86
	Work with universities: universities form the core of the research base
	Admission criteria: companies engaged in biological research and environmental protection
	Services: has a business incubator and offers a wide range of services through out-sourcing; prefers startups
	Area of activity: research in biology, pharmaceutics and medicine
	Government participation: active financial support
9. **Turku Science Park** (*Finland*)	**Founded in:** 1988
	Area: 500 hectares (premises — 250,000 m^2)
	Number of organizations: 160
	Work with universities: universities take part in research and technology commer-cialization
	Admission criteria: forestry companies are preferred
	Services: has a business incubator, offers preferential tariffs and a flexible rent-paying scheme
	Area of activity: social-economic development of the region and commercialization in the sphere of electronics, alternative energy sources, biological and pharmaceutical research
	Government participation: is jointly owned by the state and private organizations
10. **Kechnec** (*Slovakia*)	**Founded in:** 200(?)
	Area: 80 hectares
	Number of employees: more than 1000 (more than 3000 jobs were created)
	Number of organizations: 19
	Work with universities: Technical University, Pavol Josef Safarik Univeristy and Veterinary Medicine University
	Admission criteria: pharmaceutical, production organizations
	Services: logistical center, consultancy services

Table 1 Continuation

Technopark	Characteristics
11. **Kulim Hi-Tech Park** (*Malaysia*)	**Founded in:** 1996
	Area: 1700 hectares (premises — 133,000 m^2)
	Number of employees: more than 18,500
	Number of organizations: 59 companies (of which 22 are production companies and 37 are auxiliary)
	Work with universities: interaction as part of innovative development
	Admission criteria: R&D companies that develop innovative technologies and production
	Services: has a business incubator and provides outsources services; companies use simplified taxation schemes and enjoy tax breaks
	Area of activity: specializes in developing electronics, biology, pharmaceutics, medicine and also in research in physics and optics
	Government participation: government plays a key role in management; much is owned by a managing company
12. **One-North** (*Singapore*)	**Founded in:** 2001
	Area: 200 hectares (premises — 340,000 m^2)
	Number of employees: more than 3200
	Work with universities: universities play an auxiliary role
	Admission criteria: research in physics, biotechnology, R&D
	Services: more than 60% of the area is used by laboratories; some services are offered on the basis of outsourcing; simplified taxation is available
	Area of activity: development of science and innovations in the field of information and communications, medicine and physics
	Government participation: is government-owned

Based on the analysis of the activities and structure of the above technoparks the following recommendations can be made to improve the activities of technoparks in the field of science-intensive development:

- to select 'at the entrance' companies that are not engaged in active R&D;
- to offer financial inducements to resident companies to develop science-intensive technologies;
- to provide resident companies with research equipment and infrastructure;
- to encourage interaction of resident companies with science, education and business (including international structures) and government institutions;
- to actively commercialize scientific results.

To ensure effective commercialization of research results and large-scale investment the location of technoparks should meet the following requirements: availability of skilled labor; universities and other educational institutions (including the secondary professional education); an international airport and railway or waterway logistics (accessibility of a transport hub is desirable).

There is no direct correlation between the size of the technopark and its success. Today medium and small-sized techoparks prevail, but this is mainly due to the high costs of maintaining a large territory [19]. Most of the technoparks have government support. The architecture of most technoparks can be divided into two types: a structured territory with clear boundaries and a uniform style, and the chaotic type with no clear division of zones or requirements to the exterior and layout of buildings. Technoparks

on the structured territories have a wide range of services and more rigid criteria for resident status.

Modern technologies develop in cycles, but unevenly, which means that the sustainable innovative growth requires the support of flexible and responsive organization forms in the business engaged in developing new technologies. Innovative entrepreneurship is often exposed to substantial risks, and its survival depends on the institutional interaction mechanisms. One instrument for improving innovative entrepreneurship is the technopark for it allows not only to develop science-intensive technologies and convergence, but also to promote commercialization. Today the work of many Russian technoparks is focused on business at the expense of innovations. Technoparks, in addition to innovations, can aim at developing a region or an economic sector, but research initiatives are desirable as was proven by the analysis of 12 successful international technoparks. If this requirement is not met, the technopark fails its role as a role as driver of innovation and its work becomes ineffective.

Innovative organizations play a key role in the contemporary governance and social development. The mechanisms of creating companies that generate innovations require special social, economic and cultural conditions, and the world experience shows that the creation of technoparks still goes a long way to meet that requirement.

NOTES

(1) According the Law of the USSR 'On Inventions in the USSR" (31.05.1991 No. 22131. http://www.consultant.ru/document/cons_doc_LAW_18406.
(2) According to the Rospatent data. http//www.fips.ru/sitgedocs/a_iz_akt_2015.pdf.
(3) Sometimes also 'innovation park', 'techno-pol', 'technological park', 'technological area', 'techno-zone', 'research park', 'techno-city', 'science park', 'IT park', etc.
(4) Hewlett-Packard, Electronic Arts, Sun Microsystems, Nvidia, Yahoo!, Cisco Systems, Silicon Graphics, Google, etc.
(5) International Association of Science Parks. http://www.iaspws.
(6) According to various sources, up to 90% of SIEs survive in technoparks with business incubators.
(7) Without the science cities that work on such territories for more than 40 years.
(8) Research and Development; sometimes a synonym of the Russian acronym *NIOKR*.

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ТЕХНОПАРКИ И НАУКОЕМКИЕ ПРОИЗВОДСТВА: АНАЛИЗ ПЕРЕДОВОГО ОПЫТА*

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Для социального и экономического развития государства большое значение имеет создание и внедрение наукоемких технологий. Особенности современного технологического уклада обусловили потребность объединения научных и технических подходов в процессе инновационного развития. Создание и внедрение инноваций необходимо для модернизации отечественной экономики и повышения эффективности российских компаний. При этом без постоянного совершенствования науки и образования происходит социальная и культурная стагнация государства, в то время как общемировая тенденция изменения и совершенствования производства предполагает формирование новых форматов экономического взаимодействия, в которых доминирующую роль играют наукоемкие и конвергирующие технологии. В настоящее время для создания наукоемких разработок требуется полноценное институциональное взаимодействие, предполагающее совместную деятельность ряда заинтересованных сторон. В связи с этим приобретает актуальность развитие особых территорий, где формируются экономические, инфраструктурные и социокультурные условия, необходимые для создания новых технологий. Технопарки выступают одним из наиболее популярных форматов устройства территорий подобного рода. На сегодняшний день в Российской Федерации функционирует значительное количество технопарков, при этом показатели их деятельности не всегда удовлетворительны, она нуждается в оптимизации, особенно с точки зрения повышения эффективности разработки наукоемких технологий. Чтобы найти наиболее эффективные пути повышения качества деятельности российских технопарков, был проанализирован опыт 12 успешных зарубежных образцов и разработаны рекомендации по совершенствованию системы управления российскими технопарками в направлении повышения эффективности научной и инновационной деятельности. В статье обозначены особенности создания наукоемких технологий; проблемы, с которыми сталкиваются инновационные организации; роль технопарков в обеспечении инновационного потенциала государства; форматы и структура современных технопарков, а также рекомендации, позволяющие повысить эффективность их работы по созданию и развитию наукоемких технологий. В статье представлен опыт изучения технопарков российскими учеными за последние десять лет, на основе которого авторы стремятся определить основные способы оптимизации и модернизации деятельности российских технопарков в целях усиления их роли в инновационном развитии государства.

Ключевые слова: технопарки; наукоемкие технологии; NBIC-конвергенция; инновации; бизнес-инкубаторы; национальная инновационная стратегия

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