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Networking for sustainable Foresight: A Russian study

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ABSTRACT

A key element of any government's Science, Technology and Innovation policy is stable analytical infrastructure to support strategic decision making. Experience from many countries shows that substantial policy decision making requires collecting and analysing a broad range of information to develop proactive and future-oriented policies. Accordingly, infrastructure providing this information as well as evidence for policy-making must possess the capabilities for collecting, assessing, and processing information. However, information in this context is highly specific and subject related information, which is frequently embodied within expert knowledge holders. Therefore, information management in this light imposes special challenges on infrastructure.

The present study discusses some methodological approaches and practical studies to set up a network of STI Foresight network in Russia, integrated into the national Foresight and planning system. We outline the principles for goal setting, network architecture, creating a network of experts, selecting key information products, and methodological support. Russia's STI Foresight network, built on principles presented here, has been fully operational since 2011 and provides expertise on a large scale for a variety of governmental and industry organizations.

1. Introduction

Today, sustainable economic development is largely determined by how quickly countries react to the changing environment: to counter threats, and utilize opportunities. Depending on the economic system, both developed and developing countries are creating their own early warning mechanisms to foresee emerging trends and challenges which can significantly affect their competitiveness (Gokhberg and Sokolov, 2013). In countries with a dominant public sector (e.g. China or Russia), such systems are initiated by the government (top-down approach); in countries where the private sector plays a major role (e.g. the US), large corporations have for decades been setting up their own centres to monitor and analyse information regarding emerging global trends (bottom-up approach). A combination of these two approaches sets up a fully-fledged infrastructure for a long-term strategic vision and provides a flexible instrument for dealing with challenges.

Certain global challenges have become more urgent now due to a combination of faster R&D commercialization, radical changes in consumer behaviour, and evolving key global value chains. These issues dictate the need to compile an adequate portfolio of relevant measures, comprising science, technology, and innovation (STI) policies and private sector initiatives (Gokhberg et al., 2016).

The mass development of technologies and the emergence of entirely new technological fields and product groups at the juncture of thematic fields such as bioinformatics technologies, photonics, and additive technologies, require new STI policy instruments. They also necessitate the establishment of comprehensive operational processes alongside the formation of a national technology forecasting system, which would provide expert analytical support for government bodies, large sectorial companies, and academia. Developing expert infrastructure on the basis of a Foresight network will help to establish horizontal connections between scientific centres, higher education institutions, and companies operating in the real sector of the economy. These centres will also help create consortiums capable of carrying out large-scale projects in breakthrough thematic areas of R&D on the basis of these connections.

A major challenge in this ongoing desire to change the STI landscape is the widespread use of Foresight methods which give a more complete and comprehensive picture of the future development of an industry, product, or technological group (Miles, 2010; Miles et al., 2008; Rohrbeck and Schwarz, 2013; Meissner et al., 2013).

Essentially, Foresight, as a comprehensive instrument to look into the future, entails forecasting and implementing new methodical and organizational procedures to select and involve science, technology and business experts (Meissner and Sokolov, 2013). As part of this set of procedures, different areas of work are taken into account, for which various experts are called upon to conceptualize, structure, and classify priority fields, participate in surveys, validate results, and develop foresight and analytical materials (Afanasyev et al., 2014).

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Furthermore, a balanced number of experts from different thematic groups need to be involved to ensure a mature STI policy is developed.

The comprehensive involvement of different thematic groups of experts at different stages of the Foresight network's activity will allow new science, technology and product developments to be analysed from different perspectives. In addition, all stages of expert analytical support for decision making in government and science, technology and innovation policy for all major industries will be covered comprehensively.

To establish a balanced STI Foresight network i.e. a network geared towards solving the problems of different government and commercial organizations, we need to take stock of three critically important aspects:

1. The most important aspect is the organization of a range of interrelated processes to support organizational, methodological, and technological functioning of the forecasting system;
2. The completeness of the content coverage and accounting for the specialization of all priority development areas in STI are extremely important to form a consistent picture of the current state of the STI landscape;
3. Establishing connections between different STI forecasting fields to diffuse and reproduce methodical practices, results from monitoring of STI development in priority areas, and the overall information technology architecture of the STI forecasting system.

The Foresight methodology, traditionally seen as a key tool for shaping the future (Miles, 2010; Miles et al., 2008; Elias et al., 2015), helps us formulate queries for a network of industrial Foresight centres. Such a network can serve as infrastructure that assists decision making in the STI sphere. Therefore, the central research questions this article addresses are:

1. How to create an adequate architecture for a network of industrial Foresight centres, keeping in mind that they each have specific goals and objectives, and how to integrate this network into the framework of a wider national STI Foresight and planning system?
2. As a pioneering country in the field of national-level planning of STI development, which of Russia's experiences are generalizable and can be transferred to nations wishing to approach global challenges systematically in search of relevant 'global answers'?

This paper describes a network of industry centres for STI forecasting (hereafter, Foresight centres). It extends existing knowledge on Foresight by discussing new organizational and methodological approaches to create comprehensive expert and analytical infrastructure for STI policy support on the national level.

The activities carried out by Foresight centres, in close coordination with other infrastructural STI policy instruments, and these centres' integration into a network of industry leaders in technology will provide independent expert assessments about the quality of strategic documents under development. Hence, the Foresight centres will also help form the necessary conditions for large-scale implementation of STI forecasting results towards strategic industry planning practice. The considerable experience of conducting national foresight studies was used in establishing Russian National Foresight network (Chulok, 2009; Poznyak and Shashnov, 2011; Shashnov and Sokolova, 2013; Sokolov and Chulok, 2012; Sokolov, 2009).

For each of the stages in establishing the network, this paper presents methodical approaches to organize processes for the activities during the pilot operation of the network.

2. Established Foresight networks – an overview of best world's practice

Establishing national Foresight networks and providing adequate methodological and organizational support to them is a major, complex objective that involves several stages. We identified more than 25 Foresight networks all over the world and selected a few that were mature and relevant to our research question. Examples of existing national Foresight networks we studied include the National Foresight Network of Finland (The Finnish National Foresight Network, 2015) and Foresight Canada (The Canadian Foresight Network, 2015). On the international level, the Joint Institute for Innovation Policy (The Joint Institute for Innovation Policy, 2015) is functioning quite efficiently, while the United Nations Industrial Development Organization (UNIDO)-sponsored Eurasian Virtual Centre on Technology Foresight (United Nations Industrial Organization, 2015) is currently being set up. The selection was done by assessing each Foresight network against the following criteria:

- Sustainability of relationships between the network participants;
- Links with various Foresight activities including implementation of Foresight studies, disseminating results, exchanging with other research studies, involving experts, etc.

Following this assessment, we analysed in depth four networks.

Finland has a developed and multifaceted national Foresight network (The Finnish National Foresight Network, 2015). It was established in 2006 by the Sitra Foundation; since 2015, the foundation coordinates the Foresight network jointly with the Prime Minister's Office. The National Foresight Network's goal is to provide adequate information about new challenges facing Finland and about related opportunities to all stakeholders – to discuss and analyse them, and incorporate them in decision making on various governance levels. The network is also supposed to hold Foresight fora, issue reviews and 'atlases of the future', and organize training events (The Finnish Prime Minister's Office, 2014).

The Foresight network receives practical support from the Government Foresight Group which promotes the application of the results in strategic decision making in the STI sphere. The network comprises representatives of government ministries and other agencies, regional councils, universities, private companies, and research centres. It is an open network, in which participants can set up other specialized 'targeted networks' to meet their own requirements.

Close cooperation between members of various organizations when implementing Foresight programmes is supposed to significantly increase their efficiency and promote application of their results, thanks to better opportunities to plan their applications early on.

Information support of the network is provided via the official website. In addition, the network maintains a specialized information channel – the so-called 'Foresight Fridays' which are held monthly and include presentations, courses, and various Foresight-related network activities. These events are open to everybody interested in Foresight studies.

An example of a national Foresight network built around an independent organization is Foresight Canada (The Canadian Foresight Network, 2015). Its objective is to promote high-level professional Foresight studies. The network provides opportunities for interaction and information exchanges between participants – Foresight practitioners employed in various sectors of the economy. It also conducts monitoring of Foresight studies and other activities of various organizations and individual researchers in relevant areas. Members of the network implement Foresight projects, provide consulting, education, and training services, and organize various workshops.

Participants of the Public Sector Foresight Network pursue similar objectives: they discuss current and future Foresight projects, and share relevant best practices and results (Institute for Alternative Futures, 2015). However, membership is limited to those who apply Foresight methodology for government agencies.

The Joint Institute for Innovation Policy that has operated since 2008 is an example of an efficient international network (The Joint Institute for Innovation Policy, 2015). The institute provides intellectual support to decision making concerning the implementation of STI policies. It is a closed network established by four leading research and technological organizations: TNO (the Netherlands), VTT (Finland), Joanneum Research

(Austria), and Tecnalia (Spain). About 170 researchers employed by the founding organizations participate in the institute's activities.

The institute's responsibilities include assessing STI development prospects, STI policies, conducting Foresight studies, evaluation of technologies, horizon scanning, and analysing innovation activities and innovation systems.

One of the institute's major competitive advantages is that its member organizations pursue interdisciplinary activities. They have significant experience in conducting Foresight studies, and can offer services which require the expertise of top-level professionals who specialize in different fields.

Another example of an international Foresight network is the Eurasian Virtual Centre on Technology Foresight for CEE/NIS (Central and Eastern Europe and Newly Independent States) sponsored by the UNIDO (United Nations Industrial Organization (UNIDO), 2015). This network's objective is to provide methodological and information support for promoting STI Foresight as an important strategic decision-making tool for government agencies, businesses, and R&D centres to improve their competitiveness and innovation level.

Currently, the Eurasian Virtual Centre comprises organizations specializing in STI Foresight in 14 different countries. At its core are organizations with the status of a Regional UNIDO Centre on Technology Foresight such as the Technology Centre ASCR in Hungary, the Institute for Fundamental Technological Research of the Polish Academy of Sciences, and the International Research and Educational Foresight Centre in the National Research University Higher School of Economics of Russia (NRU HSE). The whole network is coordinated by UNIDO.

Regional Foresight centres perform the following main functions: coordination and provision of consulting services for Foresight projects implemented in their regions; promotion of networking between the member Foresight organizations and individual experts; development of technology Foresight information resources; dissemination of information about Foresight studies' results and potential for their practical application; developing educational and training programmes; setting up and supporting international Foresight projects (Keenan, 2006).

Another similar network – the APEC Technology Foresight Network – was established to pursue largely similar objectives. Created in 2001 on the basis of the APEC Centre for Technology Foresight, it was expected to coordinate activities of the APEC member countries participating in technology Foresight studies, facilitate the sharing of best Foresight practices and findings from Foresight projects (APEC Center for Technology Foresight, 2015; Mayuree, 2004). Currently however, no information about this network's activities is publicly available, and its website is no longer maintained.

Table 1 presents the main characteristics of existing multifaceted national and supranational Foresight networks.

In addition to multifaceted Foresight networks, there are networks with narrower specializations, which usually limit their activities to integrating and disseminating the results of completed Foresight studies. These include, for example, the European Foresight Platform (European Foresight Platform, 2015) and Interconnecting Knowledge (Interconnecting Knowledge, 2015).

The large-scale study of the principles of distributed Foresight community for many years carried out under the auspices of UNIDO. Leading expert of UNIDO Ricardo Fonseca (Ricardo Seidl da Fonseca) (Fonseca, 2002) defines the following key requirements for mature Foresight networks:

- the ability to perform complex Foresight studies;
- the ability to generate a wide range of Foresight materials, based on a combination of different competencies of the expert community;
- the need for close interaction between the key stakeholders and holders of knowledge;
- the availability of knowledge repositories;
- the adherence to the concept of ‘information as a business opportunity’;
- the mechanism of institutionalized virtual associations;
- the usage of modern software tools.

As we can see, Foresight networks are established to combine their participants' efforts and create widely accessible information resources that can facilitate STI policy making. There are plenty of similarities in the activities of these Foresight networks, especially in the performance of a number of key functions ensuring more efficient conduct of Foresight studies and use of their results.

These functions are:

- monitoring the projects, organizations and persons active in the field of network participants' interests;
- bringing together Foresight experts, decision makers, research community, business and NGOs;
- establishing better usage of expert knowledge;
- coordinating Foresight activities, including joint implementation of complex Foresight projects;
- sharing of best practices in conducting Foresight studies, creating an inventory of current technology Foresight techniques;
- information disseminating on the results of performed Foresight projects;
- organizing education and training programmes.

Generally, the longer and more active the Foresight network, the wider the range of functions performed. Some functions are carried out by almost all the participants of Foresight networks while others are done by some of them.

Summarizing the practical experience and important characteristics of the Foresight networks described above, six major aspects can be identified to make a typology (see Fig. 1).

The first three characteristics taken together reflect the networks' thematic specialization, their particular objectives, and productivity. FNFN and JIIP networks are oriented more towards integrated subject areas, and deal with various science and technology (S&T) objectives. Efficiency of these networks' Foresight activities can be increased through the close cooperation of all relevant stakeholders, particularly in the scope of integrated Foresight projects. The crucial success factors of such projects include having a sufficient number of strong participants, significant experience of conducting high-level Foresight studies, and access to adequate financial and human resources which could be efficiently pooled to deal with difficult, complex issues such as evaluating future development prospects and selecting the best available options.

The network's full coverage of subject areas and high-quality interdisciplinary interaction are achieved by involving a wide circle of participants (FNFN), representing various sectors of the economy (CN), or by recruiting several strong organizations engaged in interdisciplinary research (JIIP).

Ongoing S&T Foresight studies are more typical of FNFN and JIIP networks. For the first network, this is due to its ongoing participation in supporting national S&T and innovation policies. For JIIP, this is in contrast due to its high-level reputation and much in-demand professional services, both in the network's founding countries and in the EU generally (technology Foresight, scanning, benchmarking, etc.)

An important asset of a vigorous Foresight network is access to a large pool of highly skilled experts, with an opportunity to quickly engage top-level experts with relevant qualifications. The JIIP network deserves a special note in this regard: a significant number of experts with required skills work either directly for the network or for its founding organizations. In other networks, expert pools are formed by regularly identifying suitable candidates through monitoring relevant professional communities and motivating the experts to keep working for the network. In terms of keeping close contact with the expert pool, FNFN should be noted for its ability to assemble specialized ‘targeted networks’.

Table 1
National and International networks: basic characteristics. Sources: The Canadian Foresight Network, 2015; The Finnish National Foresight Network, 2015; The Finnish Prime Minister's Office, 2014; The Joint Institute for Innovation Policy, 2015; United Nations Industrial Organization, 2015.

Name	Aim	Functions (tasks)	Participants	Anchor organization
National networks				
National Foresight Network (FNFN)	Promote the use of information and futures perspectives in decision making	- Gather Finnish Foresight experts and decision makers, research community, and NGOs. - Producing thematic Foresight data, brainstorming within new Foresight forums, improving the dissemination of Foresight data, - organizing training	Institutions and experts	The Prime Minister's Office, Finnish Innovation Fund SITRA
Canadian Network (CN)	Encourage, nurture, teach, research and practice strategic Foresight at a high professional level	- Track the projects, organizations and persons active in the field of Foresight, coordinating activities. - implement Foresight projects, provide consulting, education, and training services, and organize various workshops	Institutions and individuals	Foresight Canada
International networks				
Joint Institute for Innovation Policy (JIIP)	Provide intelligence to support policy making with a focus on research and innovation policy	- Carry out joint research and studies	Institutional partners	TNO (The Netherlands), VTT (Finland), Joanneum Research (Austria), Tecnalia (Spain)
Eurasian Virtual Centre on Technology Foresight (EVCTF)	Provide methodological and information support on technology Foresight to industry and innovation policy decision makers	- Networking centres and coordinating activities; - delivering training; - commissioning studies; - providing information	Institutions and practitioners	UNIDO

High visibility and broad dissemination of results are particularly apparent in the case of the EVCTF and FNFN networks. For EVCTF, promoting Foresight culture, dissemination of important Foresight studies' results and best practices are among the key characteristics, while in FNFN various forms of presenting and disseminating obtained results are a major factor of the network's success. These networks have websites reflecting their current operations, and FNFN also maintains a special ongoing information channel, Foresight Friday. All of them are open to interested Foresight users. In the other networks described above, information is only disseminated among the participants.

The sustainable operation and development of networks would only be possible under good management. FNFN, JIIP, and CN networks meet requirements for flexibility and adaptability, have sufficiently elastic interfaces for working with experts, and adequately react to emerging challenges. Another very important condition of successful network development is having a constituent (anchor) organization to coordinate the network's activities. Most of the active networks do have such anchor organizations, although their status varies from international, governmental, or research organization. All of the networks analysed here position themselves as open to new participants (except JIIP).

The main risks and threats to Foresight networks include limited funding, or its dependence on a small number of sources; excessively regulated procedures for network operations and formal requirements to participants; limited number of potential users of obtained results; and reduced interest of participants, particularly individual members, to the network's activities.

Our analysis reveals that two types of networks command the highest demand and show the highest productivity. The first is open, national-level networks oriented towards providing STI policy support and comprising a wide range of participants in the national innovation system; these networks imply wide publicity and make their output materials available to the general public. The second type comprises national or international networks based on several universally recognized interdisciplinary research centres, serving various public and private customers with only limited distribution of output materials. These two network types apply the most advanced methodological solutions and organizational approaches, which help create synergies while implementing complex Foresight projects bringing together all relevant stakeholders (researchers, government agencies, and the business community).

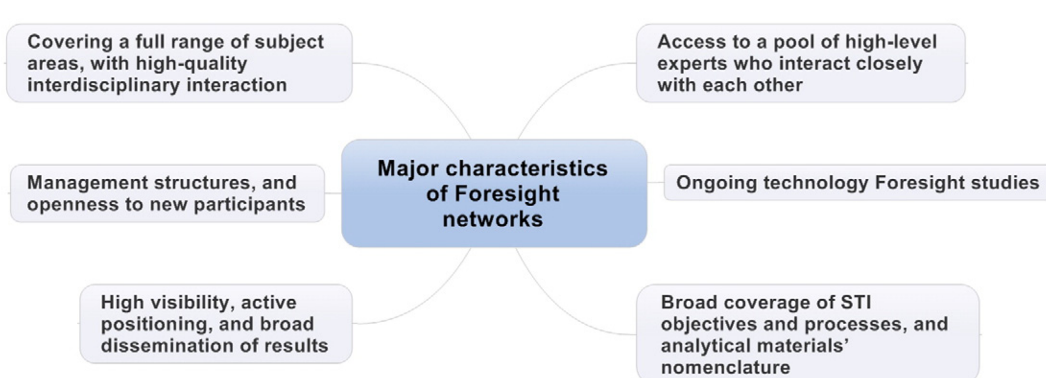

Fig. 1. Major characteristics of Foresight networks (petal diagram).

The following sections describe the key principles and common functions of the Foresight Network based on the example of the Russian STI Foresight network that is noted for carrying out a sufficiently wide range of functions.

3. Russian National Foresight network: concept and design

The roots of the Foresight network were created in 2011 at the initiative of the Russian Federal Ministry for Education and Science and supported in a coordination capacity by the Higher School of Economics (Fig. 2). In order to form the Foresight network, we selected a model based on the creation of distributed centres of competence – Foresight centres – for a number of priority STI areas (Information Technologies, Healthcare, Biotechnologies, Nanotechnologies, Transport and Space, Environment, Energy). The choice of areas was based on the structure of the National STI Foresight 2030 strategy which was recently approved by the Government of Russia (The official site of the Russian government, 2015; Ministry of Education and Science of the Russian Federation and National Research University Higher School of Economics, 2013).

In 2014–2016, the goals for the centres were modified in light of the launch of a new cycle for the National STI Foresight with broader areas and tasks.

Thus, we aimed to establish an enlarged expert community of organizations and industry experts in each area. The Foresight network must be able to continually monitor science and technology development in emerging areas of technology development, and develop Foresight and analytical material on a regular basis and at the request of government bodies and major industry players.

The established network should be tightly integrated into the state science, technology and innovation policy ecosystem (Calof and Smith, 2010; Cagnin et al., 2012). Mature and broad in scope Foresight networks could offer valuable inputs to corporate innovation and STI policy (Vecchiato and Roveda, 2010; von der Gracht et al., 2010). The internal organization of the network and individual Foresight centres must be based on common methodical principles, and use common information exchange conventions, unified document formats, and communication channels.

The network must be able to disseminate theories and best practices in Foresight studies to centres of industry-specific expertise, and prepare and train Foresight network participants as part of a single circuit of Foresight specialist training.

The Foresight network evolved progressively and we can identify four stages of its development.

In the *first stage*, we investigate the demand for products and services generated by the network. To meet this goal, a survey using a detailed questionnaire was carried out. The survey aimed to define the scope, borders and constraints, and to harmonize the activities of the Foresight network with other institutions in the national innovation system. We choose more than 30 Technological Platforms (TP) as the mechanism through which we carried out the survey. TPs are an instrument of STI policy and in Russia are a communication platform uniting key stakeholders – representatives from business, science, and education under the supervision of an appropriate ministry or agency. Given the role of TPs, we justified using them as an informational 'hub' for sending out our survey. The questionnaires were submitted to the Steering Committee of each TP, which then distributed them to their members.

The *second stage* determined the methodical approaches to coordinating the Foresight network's materials with strategic research programmes of the core technology platforms and defined the approaches to developing the Foresight network.

The *third stage* consisted of methodical training for Foresight centres' employees.

Finally, the *fourth stage* comprised practical activities organized at the Foresight centres as part of a full cycle of a science and technology Foresight study.

Fig. 3 below shows the work cycle to organize the processes behind the Foresight network's activities.

All the above-mentioned stages in creating the network will be discussed in detail in the following sections.

4. Foresight network working practices organization

4.1. Scope, borders and constraints

To define the scope and key processes of the Foresight network's activities and ensure coordinated interaction between the key aspects of the Foresight system (the Foresight network institutions and core

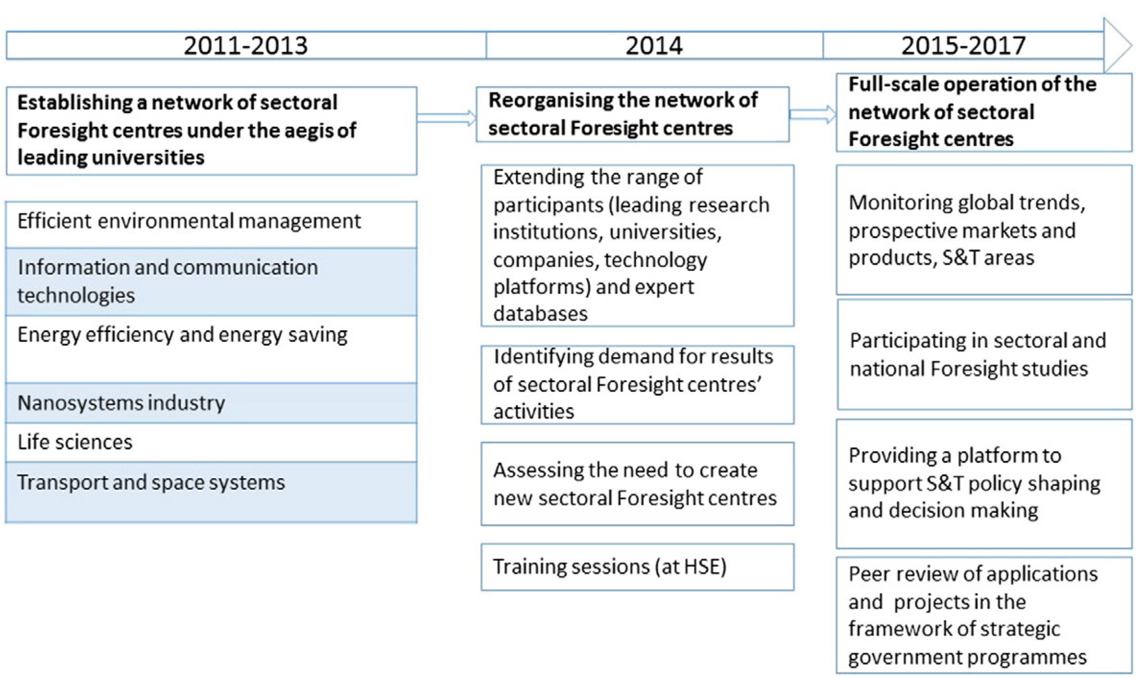

Fig. 2. Evolution of Russia's Foresight Network: key challenges.
Source: NRU HSE.

technology platforms), it was deemed reasonable to use a formalized survey of key stakeholders. The latter consist primarily of technology platforms specialized in the Foresight centre competence area.

There are more than 30 technology platforms in Russia, covering all STI areas and comprising over 700 participants – representatives of universities, companies, and R&D organizations. The main objective of this tool is to facilitate communication between various stakeholders to develop coordinated strategic research programmes. According to methodological recommendations by the Russian Ministry of Economic Development (one of the government agencies supervising technology platforms), the platforms must set their research priorities based on the results of the Russian STI Foresight 2030 approved by the Russian Government in January 2014 (The official site of the Russian government, 2015; Ministry of Education and Science of the Russian Federation and National Research University Higher School of Economics, 2013).

In light of the above, the main aims of the survey of technology platforms were to:

i) analyse the practice of using STI Foresight in the activities of core technology platforms;
ii) take into account the positions of core technology platforms when developing product ranges;
iii) consider the structure and essential make-up of the Foresight network's information products;
iv) form methodically mature Foresight network processes in line with the expectations of technology platforms.

To guarantee the consistency of the survey and ensure that the opinions of different groups of key stakeholders were taken into account, we chose to target the survey at organizations with different profiles: science/education, business and government administration.

The key questions included in the survey are:

1) *The main characteristics that are most inherent in forecasting studies*: Taking into account the intensive nature of the Foresight network's development processes and the need to correctly position the Foresight network and its key elements, both as a Foresight system in Russia and in the general context of the government's science, technology, and innovation policy, defining where efforts will be focused in the early stages of developing the Foresight network is an important aspect.
2) *Demand for Foresight, analytical and information materials from Foresight centres to support the activities of technology platforms*: Key information products produced by Foresight centres include: 'The State of Scientific and Applied Research in Russia and Globally according to the Foresight Centre Profile'; 'Evaluation of the Technological Level of Sectors of the Economy according to the Foresight Centre Profile'; 'Description of Global and National Challenges, Opportunities and Threats, and an Evaluation of their Impact on Russia;' 'Description of Prospective Markets according to the Foresight Centre Profile;' 'Description of New Products and Services according to the Foresight Centre Profile;' 'Russian and Global Centres of Expertise in Prospective Areas of Applied Research.'
3) *The importance of the Foresight network's processes to improve the efficiency of their operations and develop a Russian STI Foresight system*: Proper organization of operational processes of both the Foresight network as a whole and individual Foresight centres is critically important to the development of the Foresight network.

In this regard, ranking the operational processes of the Foresight network from the perspective of key technology platforms' priorities is an extremely important element.

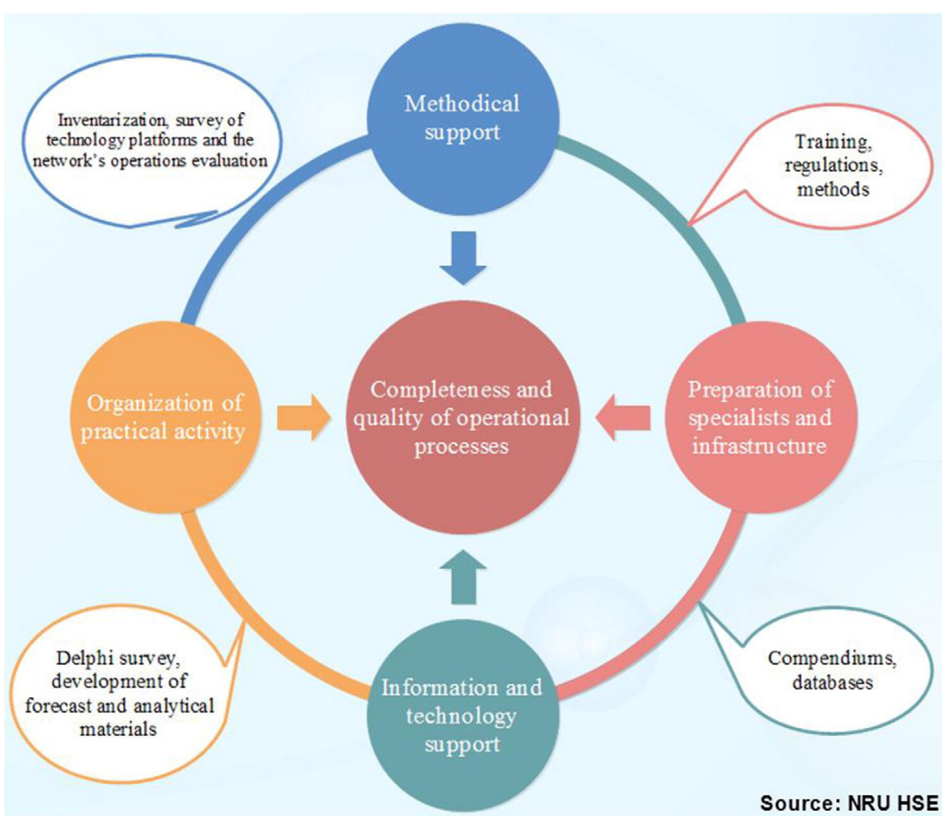

Fig. 3. Work cycle to organize the processes behind the Foresight network's activities.

To determine the key technology platforms' priorities, we organized a large-scale survey of organizations that are members of TPs. The survey covered the following issues:

regular monitoring of science and technology development in prospective areas of activity;
creating and maintaining a database of Russian industry experts;
regular expert surveys on prospective markets, products, technologies, and scientific areas;
organizing and holding expert panels on pressing issues relating to the development of priority areas;
distributing information materials, publishing digests and information reviews;
providing access to thematic selections (compendia) of information and analytical material according to the Foresight centre profile;
carrying out expert assessments of materials at the request of core ministries and technology platforms;
establishing Foresight support centres in individual priority thematic fields;coordinating the activities and harmonizing the results produced by centres in the Foresight network;
consultancy and analytical services for federal and regional authorities, development institutes, technology platforms, research institutions, higher education institutions, and industrial companies;
holding research conferences and seminars;
bibliometric analysis (Web of Science, Scopus, RSCI);
patent analysis (Europe, USA, Japan and Russia);
analysis of Russian and foreign projects according to the Foresight centre profile;
normative and procedural support for Foresight network activities.

Based on the results of the survey, we identified certain key information products and the most important operational processes in the Foresight network (Table 2).

For these products and processes, detailed models and usage scenarios were developed to build them into the activities of the Foresight network as quickly as possible.

Table 2
Key information products and the most important operational processes in the Foresight network.

Foresight network information products	– The state of scientific and applied research in Russia and the world according to the Foresight centre profile – Description of prospective markets according to the Foresight centre profile – Description of global and national challenges, opportunities and threats, and an evaluation of their impact on Russia – Evaluation of the technological level of sectors of the economy according to the Foresight centre profile – Description of new products and services according to the Foresight centre profile – Centres of expertise in prospective areas of applied research
Operational processes in the Foresight network	– constant monitoring of science and technology development in prospective areas of their activity – distributing information materials, publishing digests and information reviews – carrying out expert assessments of materials at the request of core ministries and technology platforms – creating and maintaining a database of Russian industry experts – analysis of Russian and foreign projects according to the Foresight centre profile – providing access to thematic selections (compendia) of information and analytical material according to the Foresight centre profile

4.2. Harmonization through STI ecosystem and network architecture

4.2.1. Harmonization

Integrated systematic interaction between different national technology Forecasting system institutions in Russia would allow for the development of a mature science and technology policy by the state and increased efficiency in the knowledge-generation sector (theoretical and applied sciences).

The coordination and harmonization of operational processes, results, and organizational and methodical aspects must take place across all levels of the national technology Forecasting system.

In order to comprehensively integrate the Foresight network, we developed a system for collaboration and sharing of information and procedures between the Foresight network and core technology platforms as part of the overall innovation ecosystem in Russia. We further harmonized the structure and content of key Foresight network documents and strategic research programmes at core technology platforms.

Foresight network documents, as well as forecasting and research systems of core technology platforms, are coordinated and harmonized in two ways. First, sections of technology platforms' forecasting and research systems, and parts of forecasts, and other Foresight network documents, are made coherent with one another. In Table 3 below, we match TPs' demands with what the Foresight network can offer.

4.2.2. Network architecture

The scale, diversity, and complexity of the objectives set dictate the need to choose an appropriate institutional structure for the Foresight network. Important conditions in selecting the structure and configuration of the Foresight network include:

- the need to create unified working processes to develop long-term forecasting materials on science and technology development, and inter-industry and industry-specific strategies and road maps;
- the need to maintain and create a single set of effective mechanisms to propagate a common methodology for long-term forecasts and road maps, and methodical practices and materials;
- the need to create a harmonized expert Foresight network infrastructure;
- the need to create a common information and technological infrastructure to select and accumulate knowledge in the field of science and technology forecasting.

To increase coordination, improve control, avoid discrepancies between materials, and create a unified information and technological infrastructure to support the activities of the Foresight network, it would be advisable to set up the Foresight network in a cluster structure (cluster) (Fig. 4). Within the cluster, one should identify the scientific, methodical, and technological centre in charge of coordinating and systematizing the network.

We propose that in developing the Foresight network, a scientific, methodological and technological centre will carry out the role of systematizing the network, including: (a) providing scientific methodological information, and technological and organizational support for the Foresight network; (b) coordinating and controlling the development and updating long-term forecasts of science and technology development, inter-industry and industry-specific strategies and road maps; (c) evaluating the effectiveness and analysing the activities of the network; and (d) providing systematic support for the information and software infrastructure of the network: databases of industry experts and databases of knowledge in the relevant field of STI Foresight.

In creating a cluster architecture for the network, Foresight centres will perform the role of communication hubs, establishing a sub-

Table 3
TPs' demands and the Foresight network's capabilities.

Demands from TPs	Supply from Foresight network
1. Global and national trends of markets and technologies in the platform's activities	Description of the current state of markets in industries and sectors of the economy to which the technology platform belongs, including: — evaluation of the current state of markets based on key indicators (market and main segment volumes, growth dynamics); — description of key technical and technological solutions generally characterizing the current developmental level of markets and technologies in the technology platform's area of activity; — analysis of competition in domestic and foreign markets and key segments of these markets (the main competitors of technology platform participants; their strategic positioning, strengths and weaknesses); Evaluation of the potential to develop production companies and research organizations in the technology platform's field of activity in comparison with competitors, including: – describing technical and technological solutions and skill sets which currently support the competitiveness of the platform's product manufacturers, as well as their main competitors; – analysing current support for research, engineering and technical workers at technology platform participating organizations; – general nature of access for technology platform participating organizations to existing research on technologies which have been proposed for development in the technology platform; – opportunities and limitations in the use of scientific and innovation infrastructure facilities, including shared used equipment at platform participants' premises to achieve technology platform targets.
2. Forecast of markets and technologies in the platform's activities	Forecast development of the markets for the products being developed (improved) by the technology platform, including: – identifying markets with significant opportunities to propagate the platform's products in the short-, medium- and long-term; identifying sustainable trends shaping their development; forecasting the values of key development parameters in these markets; – forms of platform products with the best market prospects in the short-, medium- and long-term. Forecast of key properties which these product types will have in the medium- and long-term (the recommendation is that quantitative and qualitative values for key technical and consumer characteristics are evaluated); – alternative products and services not related to the platform's products but capable of being competitive in the corresponding markets. SWOT analysis of alternative products and services. Identifying barriers, risks and limitations in the development of the platform's products; Forecast development of technologies covered by the platform, including: – identifying technical and technological solutions which are the most promising from the perspective of ensuring the competitiveness of the platform's product manufacturers in the short-, medium-, and long-term; – forecasting the main properties (technical and consumer characteristics) which the most promising technical and technological solutions should have in the short-, medium- and long-term (based on the market development forecast)
3. Areas of research and development showing the most promise for development within a platform	Areas of research and development in respect of which platform participants are interested in coordinating their efforts and/or collaborating with one another at the pre-competitive stage; short-, medium- and long-term development priorities in areas of cooperation between platform participants in the field of research and development at the pre-competitive stage (in terms of opening up the platform's product market and in terms of providing scientific, technical and technological support for the competitiveness of companies in these markets); groups of technologies which are proposed for development within the technology platform. areas of scientific research and development and areas where the results of research and development can be borrowed (technology imports), where there is a need, using the platform as a foundation, to provide manufacturers with critical technical and technological solutions from the perspective of their competitiveness in the platform's product market (in the medium- and long-term).

cluster within the network for a specific priority area. This would guarantee, for example, the network's external communications with consumers of the Foresight network's information and analytical products.

4.3. Methodological support and training

An important aspect of the functioning of the Foresight network is full methodical support for operational processes and the organization of a unified procedure for collaboration and information exchange both within the confines of the Foresight network and with external contractors.

In order to provide organizational and methodical support for the activities of the Foresight network, we prepared a range of methodical documents, including: (a) statute for the Foresight network; (b) statute for individual Foresight centre; (c) regulations governing collaboration between the Foresight centres and the scientific, methodical and technological centre; (d) provisions for collaboration between the Foresight network and core technology platforms, including experts from STI Foresight centres which are part of the expert base of core technology platforms; (e) a model agreement on collaboration between the Foresight network and outside organizations; and (f) regulations on continuous monitoring by the Foresight network of science and technology development in line with their activity.

With a view to establishing the basic skills of Foresight network employees in terms of creating and maintaining an expert environment and pioneering new Foresight approaches, principles, and methods, we developed a comprehensive training programme on STI Foresight theory and practice. We organized a large-scale educational programme and a series of workshops to guarantee the efficient operation of both the Foresight network and individual Foresight centres, strengthen the skills of Foresight centre employees, and properly manage processes, including scientific and methodical information and technological support for Foresight centres' activities and those of the whole network.

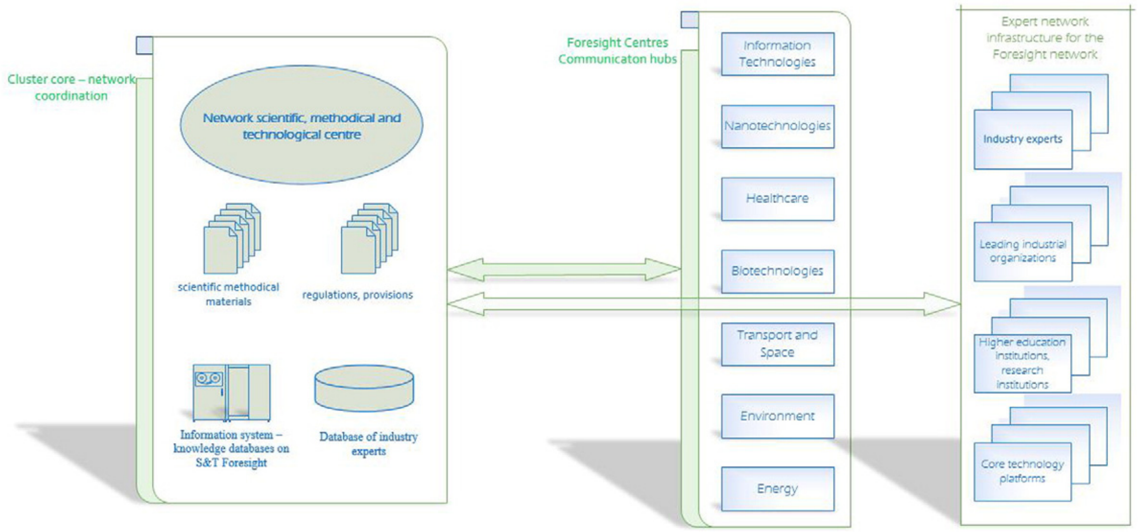

Fig. 4. Cluster architecture of the Foresight network.
Source: NRU HSE.

Further, a number of training courses need to be integrated into the Foresight network's operational processes for Foresight network employees as part of a unified training programme on 'The Theory and Practice of Foresight Network Activities'.

The training programme was based on the approved principles of consistent participant training and comprises theoretical and practical training units on: (a) methods for organizing and holding expert discussions and surveys; (b) science and technology Foresight methodology; (c) methods to analyse publication and patent performance in science and technology activities; (d) methodologies used to build a long-term Forecast and develop technology road map systems; and (e) a method for monitoring scientific and technological development.

4.4. Practical activities of the Foresight centres

An important aspect of preparing the Foresight centres for real activities as part of the Foresight network is organizing practical operational processes for the more complex tasks performed by the Foresight network: a) carrying out large-scale Delphi surveys of industry experts and b) developing Forecast and analytical materials on specialized industry-specific themes.

4.4.1. Large-scale surveys of industry experts using the Delphi method

When preparing a large-scale survey of industry experts, the structure of the questionnaire and the balanced arrangement of the questions in relation to the main elements of Foresight studies are critically important: trends, markets, products/services, and technologies. At the same time, in order to comprehensively incorporate the results from the Delphi surveys into the standard processes used to develop Forecasting and analytical materials, the questionnaires to collect expert information in all priority STI areas need to be unified. Thus, it is important to establish identical sets of parameters for the corresponding elements of a Foresight study, independent of the specifics of the subject field: import substitution, development level, inter-industry application potential, and so on.

In selecting the key characteristics of the STI development Forecast for the questionnaire, we analysed in-depth the methodical approaches and experiences of large-scale government-level surveys, particularly the practices of Delphi surveys as part of the 9th and 10th science and technology Foresight study in Japan (National Institute of Science and Technology Policy, 2010a, 2010b, 2010c). For the questionnaires, we carried out desk research on many projects linked to mass Foresight surveys (Saritas and Oner, 2004; Gnatzy et al., 2011; Czaplicka-Kolarz et al., 2009), and analysed the practices of industry Foresight projects carried out by the international science and education Foresight centre of NRU HSE (Sokolov et al., 2013).

The expert survey questionnaire includes three structural sections: global and national trends; products and product groups; and technologies and technological solutions. In terms of the content of these sections, question categories were chosen which best matched the structure of the descriptions of STI development Foresight challenges, trends, products, and technologies.

To obtain objective information from the expert survey, the views of all interested parties were taken into account including that of experts and organizations representing science, education, business, and government sectors. Fig. 5 below summarizes the breakdown of survey participants according to their profile.

When forming the expert pool for the large-scale Delphi survey, we paid most attention to the following experts and organizations:

- members of large associations (domestic and foreign);
- core ministries and agencies;
- leading domestic and foreign business organizations operating within the Russian Federation;
- participants of core technology platforms;
- core research institutes of the Russian Academy of Sciences;
- scientific research universities playing a significant role in the development of scientific Foresight;
- analytical, marketing and monitoring organizations which are up-to-speed with recent developments and discoveries.

This form of presentation reflects not only the average values for each characteristic of the STI development Forecast, but also the distribution of expert responses. This allows for a qualified judgment on the density of response consolidation and the existence of significant discrepancies in expert assessments.

The results of the large-scale survey of industry experts using the Delphi method are given in the form of a list of products/services and technologies grouped under each priority area.

4.4.2. Drafting of Foresight and analytical materials (FAM)

One of the main aims of creating the Foresight network is to provide expert analytical support for the national system of technological Forecast, core federal authorities, and industry companies. To achieve this aim through the Foresight network, several similar tasks need to be organized and carried out. These tasks would be primarily related to the drafting of a comprehensive vision for the development of priority areas in the long-term (15–20 years).

With this in mind, we went through a full cycle of drafting Foresight and analytical materials (FAM) in a predefined thematic field.

To ensure that the FAM were closely aligned with Russia's national STI priorities, we chose the national STI Forecast thematic areas as Foresight centres' themes for FAM development. Such areas are also characterized by growth in publications and patents.

In some cases, to ensure FAM coverage in interdisciplinary and closely-related STI areas, Foresight centres were advised to expand the scope of the thematic area to take into account related areas. The thematic areas for the drafting of FAM are shown in Table 4.

To ensure uniformity in the structure of documents drafted by different Foresight centres in the network as well as to ensure the completeness of the content and comprehensive presentation of relationships between elements of various materials, we developed a recommended FAM structure divided into five main sections:

1. *Most important global and national challenges capable of having the greatest effect on the thematic area*:
   a. period over which maximum effect is achieved;
   b. level of impact on Russia;
   c. which key characteristics of products/services (technologies) it affects;

2. *Description of prospective markets*:
   a. influences (demand, supply, regulatory) on the emergence of a market or market niche for the innovative product with a ranking according to the level of influence;
   b. description of new market segments;
   c. expected volumes and growth rates of markets in 2015–2020 and 2025–2030;
   d. prospective products;
   e. key players (countries, companies);
   f. barriers to entry and opportunities for Russia;

3. *Description of new products and services*:
   a. field of use, main consumer properties, unique features or advantages;
   b. technical, economic and ecological characteristics;
   c. time frame for mass diffusion of the product (in Russia/globally);
   d. basic and alternative production technologies;
   e. possible foreign and Russian producers;
   f. possible potential for import substitution;
   g. identifying the most promising areas for integration into global value chains and the formation of international alliances in science and technology

4. *Description of prospective technologies and areas of applied research*:
   a. scope of application;
   b. technical, economic and ecological characteristics;
   c. expected time to start practical use (in Russia/globally);
   d. applied scientific problems which need to be solved before the technology can be rolled out;
   e. possible suppliers of new technologies (foreign and Russian);
   f. necessary support measures from the government

5. *Global centres of expertise in certain areas of applied research. For the largest Russian and foreign centres of expertise, this section must include detailed descriptions*:
   a. general description;
   b. technologies (research areas);
   c. products/services;
   d. resource base, unique scientific and technological equipment;
   e. important projects;
   f. main patents;
   g. publications;
   h. description of partnerships with Russian and foreign centres;
   i. conferences, events, associations and programme committees (organizer and key participant);
   j. key employees (researchers).

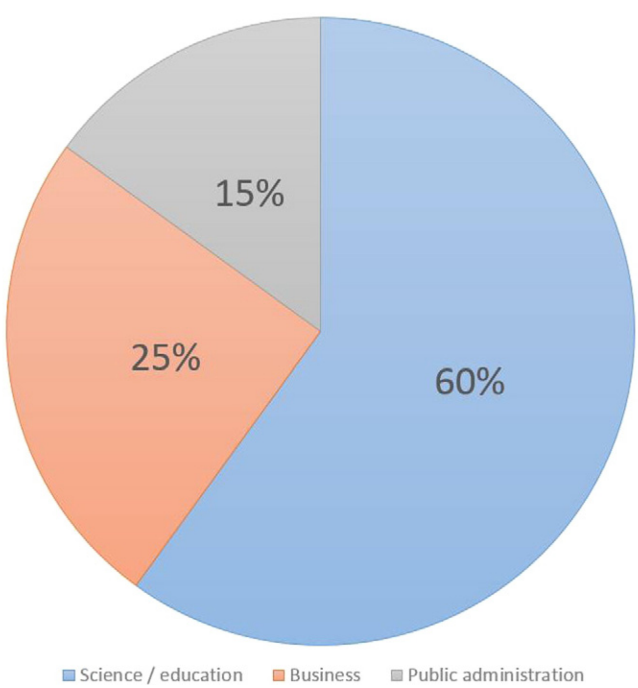

Fig. 5. The breakdown of survey participants according to their profile.

To support Foresight centres and harmonize different FAM in both volume and content, we also provide templates of FAM containing universal descriptions of prospective markets, products, technologies, and applied research areas. These templates were sent to all Foresight centres as recommendations on style, amount, and content for each of the FAM sections.

In addition to the above point to provide FAM of high quality, we involved supplementary industry experts to support Foresight centre teams. On average, NRU HSE brought in 10–15 industry experts to each Foresight centre.

Involving industry experts alongside trying to improve the quality of FAM quality have enriched the competences of Foresight centres' employees. Furthermore, these activities have the potential to be effective channels that can spread the necessary skills for carrying out methodically sound Foresight studies both within the Foresight network and beyond, to all those involved in the Russian system of technological Forecasting.

FAM contains the key parameters of prospective markets, products, technologies, and applied research areas such as the potential for import

Table 4
Thematic areas for the drafting of Foresight centres' FAM.

No.	Priority areas	Thematic field for drafting FAM
1.	Information technologies	Robotics, photonics, quantum computing
2.	Biotechnologies	Industrial biotechnologies
3.	Healthcare	Biomedical cellular technologies
4.	Nanotechnologies	Construction and functional materials
5.	Environment	Integrated development of hydrocarbon resources Research and development of Arctic resources
6.	Transport and space	Aircraft engineering Rail transport
7.	Energy	Efficient use of renewable energy sources Safe nuclear power engineering

substitution, the competitiveness of Russian companies, and the technological security of selected thematic areas. Taking into account the importance of complying with modern environmental standards, an important parameter of describing products and technologies is the environmental impact of the proposed technological solution.

5. Discussion and conclusions

This paper analyses the key methodological and practical approaches to setting up a STI Foresight network in Russia, integrated into the national Foresight and planning system.

This ambitious task has been largely determined by the profound changes in Russia's STI policy agenda over the last seven years, and the related demand for analytical infrastructure to support STI Foresight studies facilitating relevant decision making.

Compared with current practices of setting up national Foresight networks (see Section 2 above), the suggested approach helps to fully integrate the industrial Foresight centres (IFC) network with national STI mechanisms, both in terms of objective setting and the actual operations of STI policy institutes. It is practice-oriented (conducting industry-specific expert evaluations and preparing analytical reports on a wide range of emerging S&T development areas), implies ongoing monitoring on the state of the IFC network and its organizational and methodological support in order to update procedures for operations of specific centres, the whole network, and interactions with external stakeholders.

The Foresight network (established and operational under the Russian Ministry of Education and Science's sponsorship, and coordinated by the NRU HSE) comprises more than 650 organizations and 1200 experts representing academia, businesses, universities, and the expert community.

It must be realized that the efficient operation of this network depends on successfully negotiating various issues, of which the most important are:

Network members should be recognized centres of competence in extensive STI domains: joining the network implies assuming additional responsibilities, which results both in extra benefits and costs (such as personnel and network administration costs). The framework should be flexible enough to bring in 'newcomers' – organizations or research teams that can contribute 'fresh air' to the network's overall outcomes. For such 'associated members', a special status and requirements could be developed. It is also important to set objectives to meet the demands for the network's services as far as possible, and open up additional opportunities (hence the need to conduct a survey of technology platforms);

Configuration of the network is very important: how priorities are set, and more specifically, how STI subject areas are selected. On the one hand, this requires ongoing monitoring of global challenges and opportunities; on the other hand, it demands adequate understanding of existing forward-oriented results and the country's potential to achieve progress in the selected areas. It is key to keep in mind that the network's general goal is to ensure a better decision-making process in national and industry Foresight activities. From this perspective, a crucial principle to follow is to allow flexibility in priority setting – meaning presenting relevant materials for policy making but not trying to establish certain priorities;

The process of selecting, regularly evaluating, and screening out members of the network is an important task: identifying competence and skill centres should be based on a balanced set of criteria. To achieve this goal, a special coordination centre should be set up (fulfilled in the Russian case by NRU HSE) to carry out regular monitoring and refining of the STI Foresight network, provide methodological and organizational support, and training activities according to certain accepted standards.

The approaches to accomplishing these objectives presented here may be useful to other countries wanting to establish an efficient and multi-functional STI Foresight network. It is also insightful for other participants of a national innovation system. For example, companies may find these approaches of use in setting objectives for in-house monitoring centres, R&D organizations can employ them if they intend to design adequate research agendas in line with potential demand for R&D results, and universities may benefit from these approaches in adjusting their educational programmes and curricula.

The IFC network's more than five years of practical experience, ongoing coordination of and methodological support for its activities by the HSE-based coordination centre resulted in a package of best practices for the whole range of organizational, scientific, and methodological aspects of expert and analytical support to the Russian technology Foresight system. Key elements of these best practices can be generalized, and applied to building systemic national-level STI planning infrastructure.

First, close integration of the network into existing national S&T policy tools and processes is very important. To that end, particular attention should be paid to the further development of models that match the network's activities to indicators describing the hierarchy of the national technology Foresight system's objectives. Additionally, the network's organizational and methodological regulations should be regularly updated (such as regulations on individual IFCs and on the IFC network) to take into account new legislation and new S&T development strategies.

Second, to ensure expert pool consistency, monitoring studies of the IFC network's expert pool should be conducted annually, in thematic and regional perspectives. The monitoring should comprise collecting data on the IFC network's partner organizations and individual experts – authors of highly cited publications indexed by bibliometric databases – by specific activities of particular IFCs.

Third, a serious challenge in coordinating the IFC network's activities lies in standardizing the procedures employed and especially, materials produced by individual IFCs, in particular Forecasting and analytical reports in various subject areas.

Finally, common issues with the IFC network development as a key expert-based infrastructural component of the national technology Foresight system should be noted. Specifically, the insufficiently developed institutional structure of IFCs in their parent organizations often acts as a blocking mechanism, together with a lack of awareness about the role of the IFC network as a systemic, expert, and analytical part of the national technology Foresight system. Another challenge is maintaining a permanent interface between the IFCs and industrial experts (organizations and individual researchers).

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