

# FORESIGHT

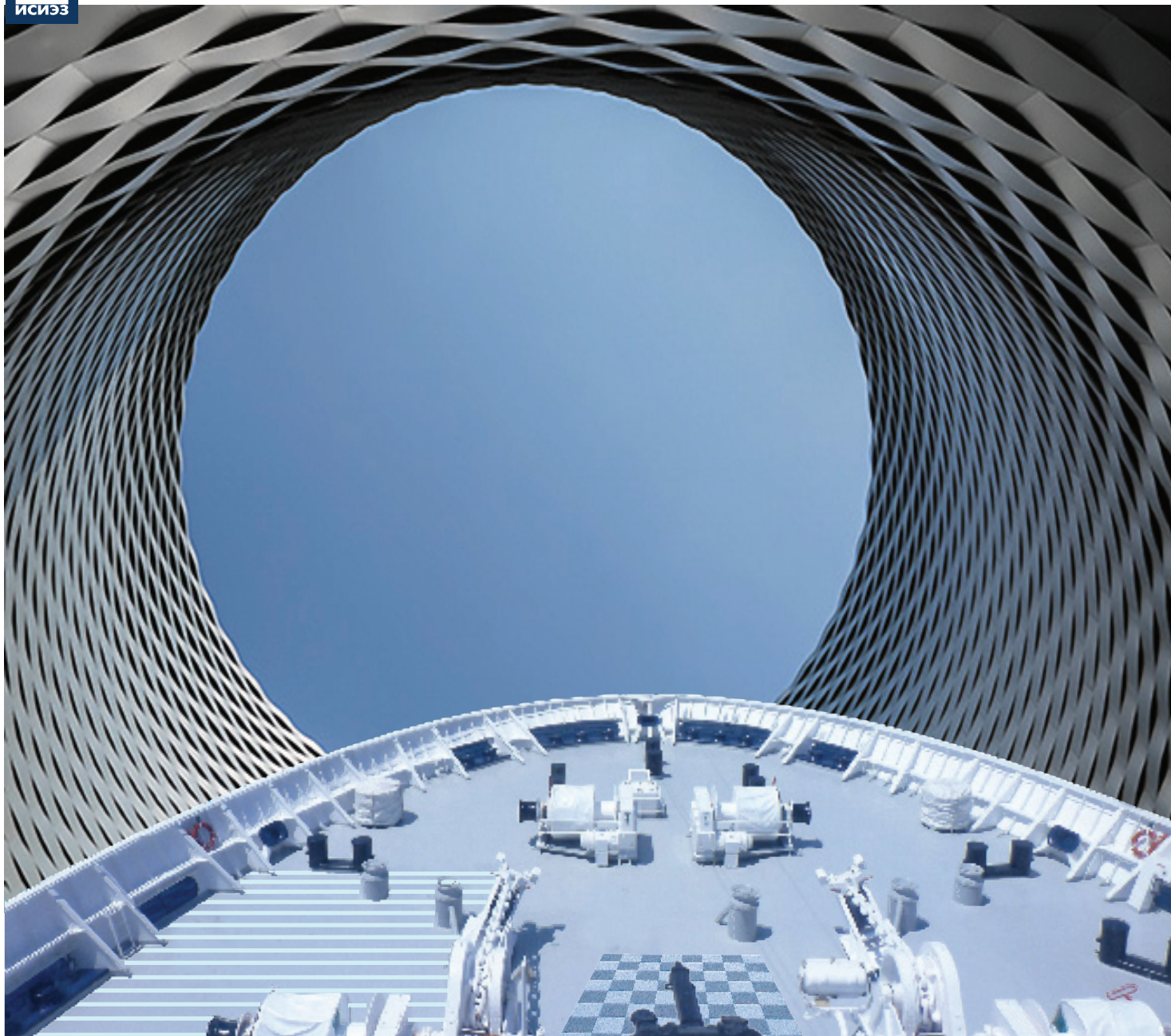
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## IN THIS ISSUE

Comparative Analysis  
of Foresight Studies

p. 6

Advanced  
Manufacturing  
Technologies

p. 16

Foresight  
in Civil Shipbuilding —  
2030

p. 30

# Foresight-Russia

National Research University  
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References to other publications must be in Harvard style and carefully checked for completeness, accuracy and consistency.



# CONTENTS

**Vol. 8 No 2 2014**

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## STRATEGIES

6

*Axel Zweck, Anette Braun, Sylvie Rijkers-Defrasne*

**International Foresight of the 2000s: Comparative Analysis**

16

*Irina Dezhina, Alexey Ponomarev*

**Advanced Manufacturing: New Emphasis  
in Industrial Development**

30

*Yuri Dekhtyaruk, Igor Karyshev, Maria Korableva, Natalia Velikanova, Anastasia Edelkina,  
Oleg Karasev, Marina Klubova, Anna Bogomolova, Natalia Dyshkant*

**Foresight in Civil Shipbuilding — 2030**

## MASTERCLASS

46

*Cristiano Cagnin*

**STI Foresight in Brazil**

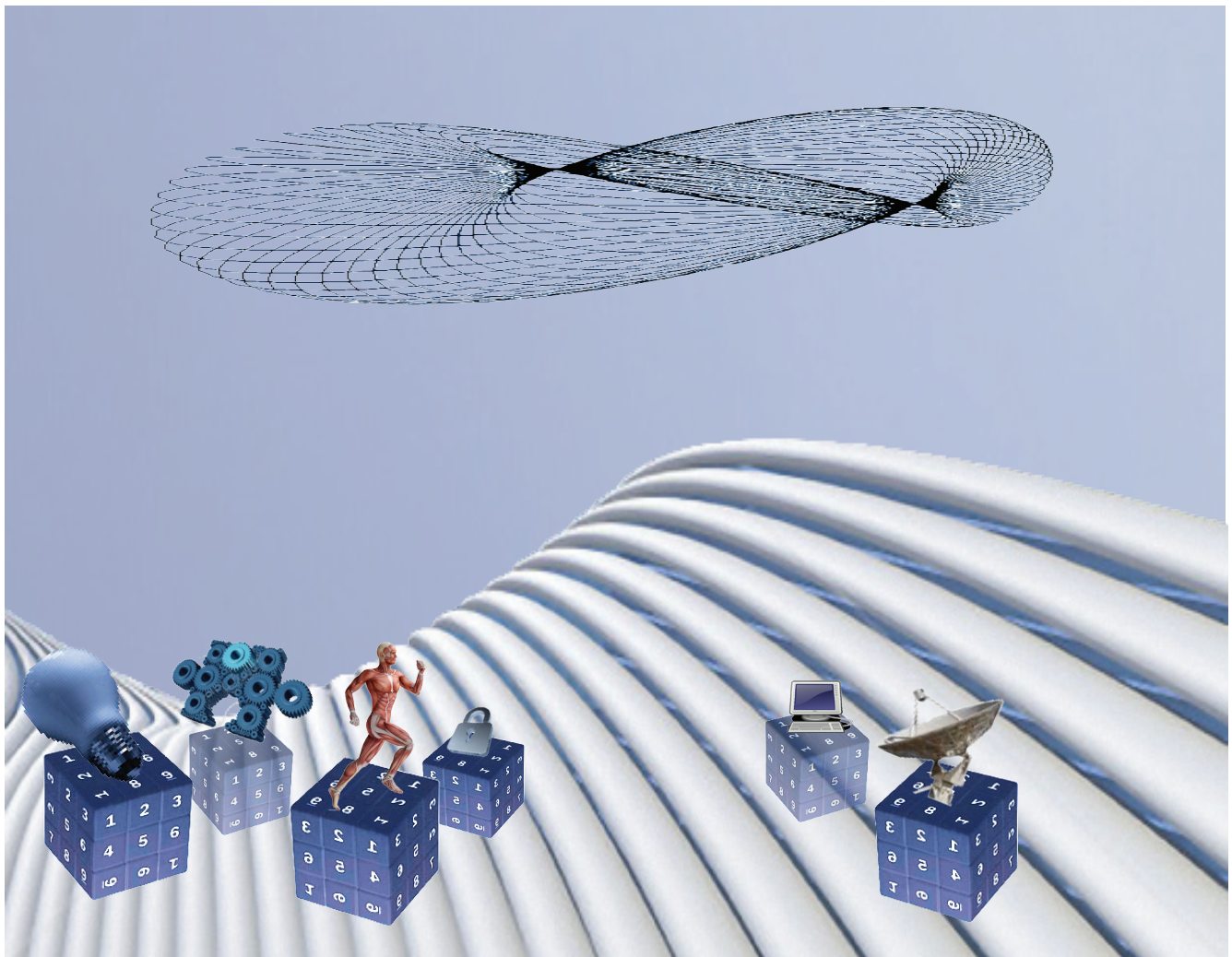
56

*Tatiana Gavrilova, Artem Alsufyev, Anna-Sophia Yanson*

**Modern Notation of Business Models: A Visual Trend**

# International Foresight of the 2000s: Comparative Analysis \*

Axel Zweck, Anette Braun, Sylvie Rijkers-Defrasne



The article summarizes the experience of technology Foresight studies carried out since 2004 in China, Japan, France, UK, USA and the EU. Despite the many differences observed between the studies, we note some significant common issues.

All the foresight studies we analysed give priority to energy; health, medicine, nutrition; biotechnology / life sciences; nano- and microsystems technology; and also to ICT, electronics, manufacturing, process and material technology, environment, defence and space technologies.

Herewith, all the technology forecasts we compared assumed that progression in sustainability/environment and ICT was a prerequisite for progress in other areas.

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\* This article is based on a contribution to the 9th Symposium for Foresight and Technology Planning, December 5 and 6, 2013, Berlin [HNI, 2013].

## Technology Foresights

Since the early 1990s, technology foresights have played an increasingly important role in the innovation and technology policy of various actors. A content analysis of technology foresights may help gain information on basic technology trends. International comparisons are a particularly efficient means to identify overall trends.

Despite the existing diversity of actors, backgrounds, and goals of such a project and despite the unavoidable associated methodological difficulties of a comparison, the meta-analysis of technology foresights carried out by the VDI Technology Centre [Braun *et al.*, 2013] contributes to an overall picture regarding the concept of future technological developments.

## Methodology

Methodologically, the study is based on three studies also carried out by the VDI Technology Centre, which elaborated on the commonalities and differences of selected European, American, and Asian studies:

1. An overview study ‘Internationale Technologieprognosen im Vergleich’ [International Technology Foresights in Comparison] from 2004 [Seiler *et al.*, 2004];
2. An update on the above publication ‘Aktuelle Technologieprognosen im internationalen Vergleich’ [Current Technology Foresights in International Comparison] from 2006 [Holtmannspötter *et al.*, 2006];
3. The study ‘Technologieprognosen — Internationaler Vergleich 2010’ [Technology Foresights — International Comparison 2010] [Holtmannspötter *et al.*, 2010].

The goal of the comparative study presented here is to provide an overview of the essential content and foci of major technology forecasts from abroad. In this way, Germany’s Federal Ministry for Education and Research (BMBF) and decision makers elsewhere will get additional information in a concise and clear form to shape research policy and strategy development. In the present study, research for suitable technology forecasts was, on the one hand, focused on Germany’s direct competitors from North America and Europe, and, on the other hand, on emerging countries and future economic powers, mainly from Asia but also from other regions of the world. Moreover, in comparison with previous studies, research was expanded through supranational activities within the context of the ‘European Forward Looking Activities’ of the European Commission and the European Technology Platforms. Based on predefined selection criteria,<sup>1</sup> we selected national technology foresights from five countries (China, France, Japan, USA and UK) as well as studies on Key Enabling Technologies (KETs) by the European Commission for the current comparative study. The studies examined differ with regard to goals, levels of detail, fields of technology, socio-economic data included, as well their time horizon. To achieve a clearly structured comparison of the technological forward-looking information, despite such differences, the studies had to be subjected to a common analysis matrix which illustrates commonalities and conspicuous deviations. Therefore, the essential information and forecasts of the respective technology studies were elaborated with regard to the following 16 topical fields:<sup>2</sup>

- Transport and Traffic, Logistics
- Aerospace Engineering
- Construction and Housing

<sup>1</sup> Inter alia, country groups, contracting parties; geographical scope and time-based delimitation; socio-economic topics, language, cf. [Braun *et al.*, 2013].

<sup>2</sup> Here, it must be pointed out that the validity of these information and forecasts was not evaluated within the context of the meta-analysis: only the most important forecasts were filtered out, regardless of whether the authors of this article considered them to be realistic, probable, improbable, unrealistic or probably even absurd.

Table 1. **Characteristics of selected technology foresights**

Country	Study	Contracting Party	Executive Institution(s)	Published in	Time Horizon	Sources
China	Science & Technology in China: Roadmap for 2050	Chinese Academy of Sciences	Various	2010-2012	2050	[CAS, 2010]
France	Technologies Clés 2015	Ministry for the Revival of Production – Directorate General for Competition, Industry and Services (DGCIS)	Institutions	2011	2015–2020	[DGCIS, 2011]
Japan	9 Japanese science and Technology forecast	Ministry of Education, Culture, Sports, Science and Technology (MEXT)	Expert Panel	2010	2039	[NISTEP, 2010a; NISTEP, 2010b; NISTEP, 2010c; NISTEP, 2010d]
UK	Technology and Innovation Futures	Government Office for Science – Department for Business, Innovation and Skills	Foresight Horizon Scanning Centre	2012	2020	[BIS, 2010; BIS, 2012]
USA	Reports of President’s Council of Advisors on Science and Technology	President of the United States of America	President’s Council of Advisors on Science and Technology (PCAST)	2010-2012	2015+	[PCAST, 2010a; PCAST, 2010b; PCAST, 2010c; PCAST, 2012a; PCAST, 2012b; PCAST, 2012c]
EU	Key Enabling Technologies, KET	European Commission	High Level Expert Group (HLEG)	2011	2020+	[European Commission, 2011; European Commission, 2012]

Source: VDI Technologiezentrum.

- Marine Technology and Shipping
- Energy
- Nano- and Microsystem Technology
- Material Science (sometimes referred to as Material Engineering)
- Production and Process Engineering
- Optical Technologies
- Information and Communication Technologies
- Electronics
- Biotechnologies and Life Sciences
- Health (including Medical Engineering) and Nutrition
- Sustainability and Environment
- Defence and Security
- Services

With this, the study provides a qualitative classification of the 16 topical fields in question — always in relation to the respective study of the individual country at the time of its development or publication. We did not carry out a quantitative assessment of the relevance of technological topics or of a state’s priorities in terms of research policy. Nor was it possible to compare the political or strategic effects of technology foresights based on the results of these studies.

### Characteristics of selected technology foresights

Within the context of the current meta-analysis, it can be stated that there are significant differences between the technology studies examined with regard to the range of topics and their depth. On the one hand, very broad-based studies exist which deal with the respective technologies only in bul-



let-point style (e.g. from Japan); on the other hand, there are studies that discuss particular fields of technology in great detail (e.g. from China). The studies from the USA are an example of a very detailed approach to specific fields of technology, which due to their large number also cover a wide range of topics.

### Content Priorities

Despite the differences between the technology studies examined, we noticed similarities in priority settings: all the studies deal exclusively with the topics of Energy, Health/Medical Engineering/Nutrition, Biotechnology/Life Sciences and Nano-/Microsystem Technology. Comparing the results of the 2013 comparative study to those of the previous studies, we observe that the discussion about the topical fields of Energy, Health, Nano-, Bio-, Optical Technologies, Environment and Aerospace Engineering gathered significant momentum over almost a decade. In contrast, topics such as ICT, Material Engineering, Electronics and Transport showed a loss of interest in comparison to previous decades. While the arising discussion about the convergence of technological fields (Biotechnology, Nanotechnology, Materials, and ICT) was the result of the analysis in the 2004 comparative study, the topic of Sustainability/Environment emerged as a demand-oriented key issue in the 2006 comparative study. In the analysis of 2010, Energy was the key issue of the technology foresight studies examined.

The specific feature of the latest comparative study (2013) is the awareness that with the *visible* key issues of Energy & Health, on the one hand, and Bio- & Nanotechnologies on the other hand, two demand areas and two technology areas were regarded as the ‘big’ issues. Moreover, it can be observed that the topics of Sustainability and Environment as well as ICT are *invisible* key issues of the current comparative study. Unlike in previous national technology foresight studies, in the latest technology forecasts these two topics are, in most cases, not regarded as independent areas; rather, their application is cross-cutting to other areas.

### Key Messages of the Technology Foresights for the Individual Topical Fields

Below, the key messages of the technology foresight studies for the individual topical fields are summarized with regard to their content. In all the technology foresight studies considered here, great attention is paid to the topic of **Energy**, attaching as much importance to coal technologies as to renewable energy sources (solar, wind, water, biomass, and geothermal), nuclear energy, and nuclear waste treatment technologies. However, even new or alternative technologies such as the non-conventional recovery of oil and gas resources as well as technologies for energy storage and saving (smart grids) and the efficient conversion/use of energy, are of special relevance. These technologies, which belong to the topic area of **Biotechnology and Life Sciences**, are highlighted as Key Enabling Technologies — they have important applications in the field of Health and Nutrition in particular, and also in Production, for example for the development of clean and sustainable process alternatives in industry and agriculture. The fields identified as forward-looking include, among others, Lab-on-a-Chip methods, further research into ‘omics’ technologies,<sup>3</sup> stem cell research and ‘tissue engineering’, synthetic biology and the application of white biotechnology in new areas (e.g. textile, paper or perfume industries). Great importance is also attached to further developments of biotechnological processes for agriculture (e.g. biological fertilizers, molecular biological plant breeding), for modern animal breeding and for resource conservation. Progress in the development of new techniques for rapid diagnosis is expected as a result of the further development of membrane techniques in microfluidics and molecular biology.

In the field of **Health, Medical Engineering and Nutrition**, statements are made on reproductive medicine, on the prevention and healing of severe chronic dis-

<sup>3</sup> As a suffix, ‘omics’ characterizes the aspects of modern biology that deal with the analysis of the entirety of similar individual elements e.g. genomics, metabolomics, proteomics, etc.

eases and infectious diseases as well as on biosafety, nutrition, and food safety. Continuing penetration of the health sector by Biotechnologies, ICTs, Nanotechnology, Microsystem and Material Engineering is forecasted. In the field of Medical Engineering, functional imaging techniques, telemedicine, personalized medicine, lab-on-chip systems, regenerative medicine, advanced instrument technology, nano-biomedical technologies as well as minimally invasive methods are said to have great potential in the future.

Much attention is also paid to the topic of **Nano- and Microsystems Technology**, in particular as a cross-cutting technology and 'Enabling Technology.' Its convergence with numerous other disciplines such as Material Engineering, Biotechnologies, and ICTs raises expectations for important technological breakthroughs. Nanomaterials, micro-apparatus and reactors, sensors and sensor networks as well as thin-film techniques are considered to have great potential. Increased use of nanotechnologies and materials in everyday applications for health, environment and energy is expected.

Important aspects, or rather forecasted developments, in the field of ICT comprise the development of a service industry for data and knowledge, the convergence between ICT and other disciplines, access to information, data, applications and services — anytime and anywhere, grid and cloud computing, the *internet of things*, next-generation networks, issues concerning data and communication security, as well as man-machine interactions.

In the field of **Production and Process Engineering**, increasing importance is attached to the use of new resources and energy sources, to technologies that increase efficiency or to reduce resource consumption, to system integration, to the development of green products in the processing industry as well as to recycling.

In the field of **Material Science**, increased importance (and progress) is expected in terms of functional, smart, and recycling-oriented, bio-inspired materials and for the issue of recycling and the reuse of materials. Moreover, progress concerning methods for non-destructive materials testing is anticipated.

In the field of **Sustainability, Environment and Resource Scarcity**, global climate change, river and environmental quality (the biological-geochemical connection between land, river, coast), urbanization, environmental quality (control and removal of environmental pollution) and biodiversity, as well as the restoration of damaged ecosystems are paramount. Discussions are also happening now about technological applications for the water environment/water ecology, air treatment, for the improvement of photocatalytic processes, the remediation of soil, waste disposal and treatment as well as for the creation of a sustainable society. Moreover, as far as resource scarcity is concerned, the field of sustainability and environment is dealt with across all other technological fields.

In the field of **Electronics**, reference is made to its convergence with other technological fields, such as micro- and nanotechnologies (increasing miniaturization, semi-conductors) and biotechnology (DNA computing). The increasing importance of power electronics and the use of electronics in communication as well as in the field of energy (solar cells, smart grid technologies, battery technology) is forecasted.

In **Defence and Security**, the focus is often on the security of ICT systems and applications, crisis management and disaster control, general civil security, prevention of crime, and also on the security of raw materials.

With regard to the topical field of **Aerospace Engineering**, innovation impetuses concerning the expansion of the human scope of action are expected from micro- and nanoelectronics, drive technologies, and other fields. In Aerospace Engineering, progress is forecasted for lightweight and

miniature spacecraft and loading capacities, as well as advancement towards the permanent stay of humans in outer space.

In **Transport and Traffic, and Logistics**, it is the development of low-emission vehicles, increasing penetration in the transport and logistics sector of ICTs (driver assistance systems), the trend towards smart transport networks and the support of resource-saving driving behaviour (e.g. car sharing) that is at the forefront of progress. The increasing importance of system engineering and complex modelling and simulation methods in the transport sector are also being discussed. According to the technology foresight studies we have examined, there is particular potential for the further use of ICTs as well as for photonics and micro- and nanoelectronics in transport, traffic and logistics.

Special market potential is seen in **Optical Technologies**, in particular in the application of photonics for imaging techniques in medicine, in photovoltaic applications and smart lighting systems as well as in 'green photonics.' Here, an increasing convergence with electronics is assumed.

Regarding the topical field of **Marine Technology and Shipping** it is expected that the industrial exploitation of seabed resources as well as the generation of wave, tidal and flow energy will be possible in future. The further ecological development of marine bioindustry and the fixation of carbon dioxide under the seabed are thought to have great potential. The same applies to the field of **Construction and Housing**, in particular in technologies for the optimization of energy efficiency and for the careful use of resources.

In the field of **Services**, new service concepts are forecasted due to the increasing hybridization of production.

### Changes in the topical fields over time

The following figures show how topical priorities have shifted over time<sup>4</sup> and which of the 16 fields of technology are highlighted, and how these fields are discussed in the studies. Thus, this comparison provides a qualitative categorization of the 16 topical fields under consideration — always in reference to a particular country at a certain point in time. However, it does not provide a quantitative assessment of the relevance of technological topics or the priorities of a country in terms of research policies. Neither is it possible, based on the results of these studies, to compare the political and strategic effect of technology foresight studies. The fields of technology which were discussed most in both the 2004 comparative study (Fig. 1) and in the current (2013) comparative study (Fig. 2) are marked in colour. In 2004, these were ICT, Electronics, and Material Sciences. Over time, a reduced analytical intensity, with a particular downward trend for ICT, could be observed in these three technological fields.

The four major topics of the 2013 comparative study — Energy, Biotechnology / Life Sciences, Health, Medical Engineering, Nutrition, and Nano- and Microsystem Technologies — have shown a clear upward trend throughout all the studies over time. The topics of Biotechnology / Life Sciences and Nano- and Microsystem Technology could even compensate a temporary downward trend (2004-2010).

At this point, the convergence between ICT and other disciplines should again be noted: many other fields of technology consider ICT as an 'Enabling Technology.' In other words, progress in ICT is often the prerequisite for further developments in other fields. Thus in later technology foresight studies, ICT is not regarded as an independent field, but its application/input is considered cross-cutting to other sectors such as Transport and Traffic, and Logistics.

<sup>4</sup> The more often a topic was dealt with, the higher it is ranked in the topic column. The pillars reflect the respective ranking of the technology fields in the comparative studies of 2004, 2006, 2010 and of the present study 2013.

Figure 1. **Historical development of topical fields which were most discussed in the comparative study of 2004**

2004	2006	2010	2013
ICT	Sustainability and Environment	Energy	Energy
Electronics	ICT	Sustainability and Environment	Biotechnology / Life Sciences
Material Science	Biotechnology / Life Sciences	Health, Medical Engineering, Nutrition	Health, Medical Engineering, Nutrition
Biotechnology / Life Sciences	Health, Medical Engineering, Nutrition	ICT	Nano- and Microsystem
Health, Medical Engineering, Nutrition	Energy	Transport and Traffic, Logistics	ICT
Production and Process Engineering	Production and Process Engineering	Biotechnology / Life Sciences	Production and Process Engineering
Energy	Material Science	Defence and Security	Sustainability and Environment
Nano- and Microsystem	Nano- and Microsystem	Construction and Housing	Material Science
Transport and Traffic, Logistics	Transport and Traffic, Logistics	Production and Process Engineering	Electronics
Defence and Security	Aerospace Engineering	Material Science	Defence and Security
Sustainability and Environment	Construction and Housing	Nano- and Microsystem	Aerospace Engineering
Aerospace Engineering	Defence and Security	Aerospace Engineering	Transport and Traffic, Logistics
Marine Technology and Shipping	Electronics	Marine Technology and Shipping	Optical Technologies
Services	Optical Technologies	Optical Technologies	Marine Technology and Shipping
Optical Technologies	Services	Services	Services
Construction and Housing	Marine Technology and Shipping	Electronics	Construction and Housing

Source: VDI Technologiezentrum.

Finally, although the topics of Electronics and Material Engineering experienced a significant decline until 2010, the current comparison shows that both fields have again risen higher on the research agenda.

### Comparison of Decades

Table 2 below illustrates the change of topics over time in technology foresight studies throughout almost a decade (2004–2013). The relative change in the relevance of topics in the technology foresight studies analysed in 2013 compared to their relevance in the comparative study of 2004 is shown as an upward, downward or constant arrow.

Table 2 demonstrates that the topics of Energy, Biotechnologies / Life Sciences, Health, Medical Engineering, Nutrition, Nano- and Microsystem Technology, Sustainability and Environment, Optical Technologies as well as Aerospace Engineering are more frequently discussed compared to in the comparative study of 2004 (although in part, interim declines could be observed).

On the other hand, the discussion about the topical fields of Material Science, Electronics, Transport, Traffic, and Logistics, Marine Technology and Shipping, Services, and Information and Communication Technologies lost their intensity within almost a decade. However, the relative frequency of analysis of Production and Process Engineering, Construction and Housing, and Defence and Security remained constant.

### Conclusion

As noted above, for the last two decades technology foresight studies gained an increasingly important role in the innovation and technology policy of many different actors. The enormous increase in technological knowhow, the growing complexity of technologies and the necessity to efficiently utilize scarce resources to boost innovation are only a few of



Figure 2. **Historical development of the topical fields most intensely discussed in the comparative study of 2013**

2004	2006	2010	2013
ICT	Sustainability and Environment	Energy	Energy
Electronics	ICT	Sustainability and Environment	Biotechnology / Life Sciences
Material Engineering	Biotechnology / Life Sciences	Health, Medical Engineering, Nutrition	Health, Medical Engineering, Nutrition
Biotechnology / Life Sciences	Health, Medical Engineering, Nutrition	ICT	Nano- and Microsystem
Health, Medical Engineering, Nutrition	Energy	Transport and Traffic, Logistics	ICT
Production and Process Engineering	Production and Process Engineering	Biotechnology / Life Sciences	Production and Process Engineering
Energy	Material Engineering	Defence and Security	Sustainability and Environment
Nano- and Microsystem	Nano- and Microsystem	Construction and Housing	Material Engineering
Transport and Traffic, Logistics	Transport and Traffic, Logistics	Production and Process Engineering	Electronics
Defence and Security	Aerospace Engineering	Material Engineering	Defence and Security
Sustainability and Environment	Construction and Housing	Nano- and Microsystem	Aerospace Engineering
Aerospace Engineering	Defence and Security	Aerospace Engineering	Transport and Traffic, Logistics
Marine Technology and Shipping	Electronics	Marine Technology and Shipping	Optical Technologies
Services	Optical Technologies	Optical Technologies	Marine Technology and Shipping
Optical Technologies	Services	Services	Services
Construction and Housing	Marine Technology and Shipping	Electronics	Construction and Housing

Source: VDI Technologiezentrum.

Table 2. **Change in topical relevance in technology foresight studies**

Topic	2004–2013
Energy	↗
Biotechnologies and Life Sciences	↗
Health (including Medical Engineering) and Nutrition	↗
Nano- and Microsystem Technology	↗
Sustainability and Environment	↗
Optical Technologies	↗
Aerospace Engineering	↗
Production and Process Engineering	→
Construction and Housing	→
Defence and Security	→
Material Science	↘
Electronics	↘
Transport and Traffic, Logistics	↘
Marine Technology and Shipping	↘
Services	↘
Information and Communication Technology	↘

Source: VDI Technologiezentrum.


the reasons. Ever shortening innovation cycles accompanied by high competitive pressure add to the growing demand for knowledge about the future (which is required for the strategic decision making of governments, international organizations and companies).

National and interdisciplinary technology foresight studies provide an insight into the assessments and expectations of governments regarding emerging technology development and in part also into the strategic planning nationally. International organizations as contracting parties of these foresight studies complement this point of view through their globally or at least supra-region-

ally, oriented assessments. Technology studies on behalf of multinational groups contribute to an industry-specific viewpoint.

In particular, Germany as an exporting nation strongly oriented towards high-technology products is dependent on the early identification of new trends and development paths. Such a need is taken into account not only by self-generated forecasts, but also by the monitoring of internationally available studies. A meta-analysis of technology foresight studies can contribute to building up an overall picture regarding future technology development and to elucidating national strengths and characteristics by deduction. Content analysis of technological foresight studies helps to acquire immediate information on basic technology trends. International comparisons are a particularly efficient way to identify overall trends.

The fourth comparative technology study carried out by the VDI Technology Centre provides an overview of the essential content and priorities of recent and important technology forecasts from abroad. It thus offers a qualitative categorization of 16 analysed topic areas — always in reference to the respective study of a country at the point of time of its preparation or publication. Within the context of this meta-analysis, we can conclude that, in part, the individual technology studies analysed differ considerably in terms of both their range of topics and their depth. On the one hand, very broad-based studies exist which deal with the respective technologies only briefly, in bullet-point style (e.g. from Japan); on the other hand, there are studies that discuss particular fields of technology in great detail (e.g. from China). The studies from the USA are an example of a very detailed approach to specific fields of technology, which, due to their large number also cover a wide range of topics. Despite the diversity of the studies analysed and the diversity of the system of concepts, it appeared that the analysis grid used here is adequate to the subject. This means that the essential information of the studies analysed could be allocated, almost without exception,<sup>5</sup> to one or two of the 16 topical fields of the analysis grid. Such a basic assessment of the appropriateness of the analysis grid has not changed over the four comparative studies conducted to date. Against this background it could be assumed that there are also only a few changes in the intensity of the overall engagement in these topical fields. At the same time, in some cases it seems that there are drastic upward and downward movements, as Table 2 illustrates. This is all the more surprising if one considers that the topic fields of the analysis grid have a high level of aggregation and technology forecasts often concern longer time horizons of 10 or more years.

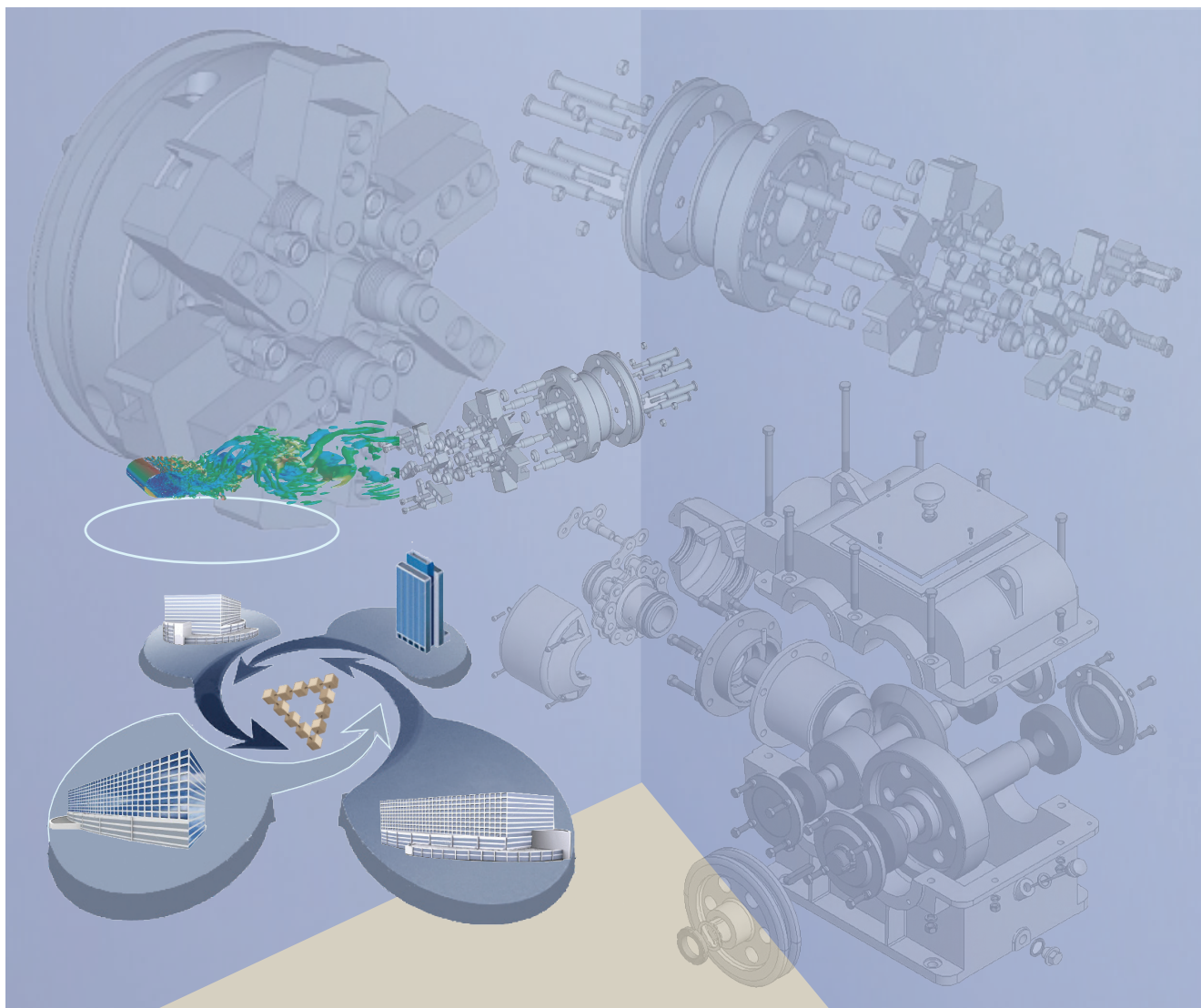
In the comparative study of 2013, we saw a clear prioritization of Energy, Health, Medical Engineering, Nutrition, Biotechnologies / Life Sciences and Nano- and Micro-system Technology topics. The technology foresight studies also dealt with the topical fields of ICT, Electronics, Production and Process Engineering and Material Science, Environment, Defence, and Aerospace Engineering. The results of all the technology foresight studies analysed, in particular in the topical fields of ‘Sustainability and Environment’ as well as ‘Information and Communication Technologies’ showed that their further development is often a prerequisite for progress in other areas. 

<sup>5</sup> The following topical fields of the 9th Japanese Technology Foresight Study were not classifiable: Strengthening of the management possible/required due to the scientific-technical progress; Infrastructure technologies for the support of the daily livelihood and the industrial basis; Observation, monitoring, simulation and forecast, assessment, consensus building.

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# Advanced Manufacturing: New Emphasis in Industrial Development

Irina Dezhina, Alexey Ponomarev



**The development of advanced manufacturing technologies produces tangible social and economic impacts and has strategic importance for strengthening competitiveness of a country's economy.**

**The article compares the capacities of Russia and the world's leading countries in the field of advanced manufacturing technologies, and outlines policy tools to support the development of such technologies.**

**Special attention is paid to the scientific and industrial consortia which aim to support promising developments at the pre-competitive stage.**

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## Keywords

advanced manufacturing; government policy; industry; consortia; new industrialization; diagnostic monitoring; policy tools



## The concept of Advanced Manufacturing

The development of advanced manufacturing technologies (sometimes called “breakthrough” technologies, to emphasize their revolutionizing effect on the production pattern) has been widely discussed in developed and newly industrialized economies over the last few years. Such attention is well-deserved as advanced technologies create new markets and industries, promote operational efficiency, competitive growth in certain industries and national economies in general. With their potential to drastically upgrade the workflow, facility management methods and the skills of the workforce, these technologies often drive changes in the economic setup. Advanced manufacturing technologies may trigger, for example, the closing of large-scale production facilities as a result of shifting to product customization and reducing the reliance on a cheap workforce. Digital technologies make the workflow more coherent. Technologically, advanced manufacturing technologies are primarily associated with 3D-printing, the Internet of things, innovative materials and robotics [MIT, 2013].

Russia lags behind developed and some developing nations in terms of advanced manufacturing practice. However, Russia still has a chance of catching up with the global leaders: the critical task is to identify the economic and technological areas to be developed for the breakthrough technologies to emerge in the country. This paper investigates the experience of foreign countries where advanced manufacturing is promoted by the government. Our methodology consisted of reviewing scientific publications and government policy documents from the USA and UK and conducting interviews in the USA with officials in charge of development and implementation of advanced manufacturing technologies.

Many studies devoted to different dissemination aspects of advanced manufacturing technologies have been undertaken for several decades. However, such aspects as customization and localization, i.e. different forms of aligning manufacturing facilities to customer needs, have only recently become priorities. In the mid-1980s and early 1990s, studies to assess the impact of some technologies on productivity and efficiency of enterprises and companies became popular [Beaton, Bull, 1987; Son, Park, 1987; Gertler, 1993; Lei et al., 1996].

The early 2010s saw a new surge in interest for advanced manufacturing technologies, when both researchers and governments focused on the new manufacturing related to localization and customization [Tassy, 2010; Gibson et al., 2010] and the respective changes in the requirements to personnel qualifications [Davis et al., 2012]. One of the recent significant papers on the subject discusses the changing approaches to localization of production facilities in the USA [Berger, 2013]. European researchers pay great attention to assessing the government-supported manufacturing technology programs, in particular, the relevant aspects of Framework Programs [Arvanitis et al., 2002], and the recent study on the potential of technological platforms in assessing advanced technologies and their promotion policy [ManuFuture-EU, 2011].

Characteristically, researchers have not yet agreed on a single definition of promising (advanced) manufacturing technologies. Nonetheless, the wording of the definitions have something in common, including, in particular, using innovative technologies to improve products and/or workflows as well as the innovative business methods. The definition of advanced manufacturing proposed by Paul Fowler, Research Director of the US National Council for Advanced Manufacturing (NACFAM) [STPI, 2010], is the best known:

‘Makes extensive use of computer, high precision, and information technologies integrated with a high performance work force in a production system capable of furnishing a heterogeneous mix of products in small or large volumes with both the efficiency of mass production and the flexibility of custom manufacturing in order to respond rapidly to customer demands.’

Later, the Institute for Defense Analyses (IDA) introduced a wider notion of advanced manufacturing into public use. This notion was elaborated based

on surveys among the scientific community, public administration and industry. Advanced manufacturing means both conventional and high-tech industries where existing materials are improved and/or new materials, products and processes are created by implementing the achievements of science and technology, high-precision and information and communications technologies (ICT). These achievements are integrated with a high-performance workforce, the innovative business or organizational models [Shipp *et al.*, 2012].

Professionals have become increasingly interested in the large-scale customization feature of advanced technologies [Piller, Tseng, 2010; Boër *et al.*, 2013], meaning large-scale manufacturing of customized (consumer and capital) goods. That is comparable with high-volume manufacturing in terms of efficiency and differentiation and this creates economic advantages of advanced manufacturing for potential users. Customization envisages transferring certain functions related to a finished product technological design to suppliers, and therefore it becomes essential to obtain suppliers' constant feedback which can be taken into account in subsequent manufacturing. Hence, customization has both service and production dimensions.

For several decades, attempts to set up large-scale customized production facilities have been underway. The additive technologies that emerged have prompted this process, although forging an efficient teamwork along the entire value chain, including integrating into the supply system, is the fundamental difficulty.

In Russia, the term “advanced manufacturing” is used in statistical accounting, where it means “flow processes including microelectronics or computer controlled machinery, accessories, equipment and devices that are used in designing, manufacturing or processing” [HSE, 2014, page 398]. Obviously, this definition does not reflect particular features of the modern developmental stage in manufacturing technologies, such as large-scale customization.

Thus, the new understanding of advanced manufacturing covers the following dimensions:

1. Technological substitution that leads to major improvement of existing products or to the creation of entirely new ones;
2. Computer-aided manufacturing that imposes new requirements on professional qualifications;
3. Customization of production facilities i.e. their flexible adaptation to customer needs;
4. Localization: cutting down costs by procurement savings and ensuring proximity to the consumer (customer);
5. Economic efficiency related either to cost cutting compared with large-scale manufacturing or to resource conservation, higher productivity, investment appeal and competitiveness.

In this article, we try to limit the range of key technologies (in the technical sense of the term) to the development of production facilities with certain economic features (low-cost customized products and manufacturing that can be decentralized). The following definition is proposed for the purpose:

‘Promising (advanced) manufacturing technologies is a set of processes intended for high tech designing and manufacturing of customized items (goods) of different complexity, with the value comparable to the value of mass-produced commodities, in particular, in low-wage countries.’

This group of flow processes makes it possible to decentralize development and manufacturing, while ensuring significant logistic advantages in the creation and promotion of goods to the market, reduction in their cost, and the cost of their delivery to the end consumer. On the one hand, these pro-

cesses depend on efficient information dissemination, and the level of automation and computerization. On the other hand, they depend on new materials, and research and development (R&D) in physics, biology, and related fields.

Advanced manufacturing may be technically described using the five key areas of the transdisciplinary research group focus. To work in the areas, participants should be able to use meta languages of each appropriate field. Based on different approaches to defining the top priority areas of the advanced manufacturing technologies [MIT, 2013; ARTEMIS, 2013; NIST, 2013, p. 3], we highlight the following:

1. Flow process control systems, including sensors to monitor equipment, material flow parameters and the state (size, composition et al.) of created (processed, grown) items;
2. Multi-dimensional modeling of complex products that enables you to improve their different parameters (durability, service life and, possibly, the manufacturing flow). Such modeling systems allow an item to be customized through modification for customized or small-scale manufacturing;
3. Intellectual production management systems (improvement of external and internal procurement, process flow modes), in particular, in robototronics and the so-called 'Internet of things';
4. Material item creation and transformation (growing) system, in particular, 3D-printing; the infusion technologies that become of greater significance; promising surface processing methods and thermoplastic polymer handling methods. Growth technologies in their broad meaning are critical for this area;
5. Materials efficient in the creation of promising actuation devices (first of all, growth technologies) — composition materials, as well as the materials demonstrating their properties in subtle structures.

The progress in these fields may create some visible cost advantages in addressing the multiple production problems. The production infrastructures based on these technologies are regulated by industrial, innovation, scientific and educational policies. Educational policy is becoming increasingly intertwined with the new industrial policy, due to changes in manufacturers' needs, exhaustion of the conventional regulation mechanisms, as well as some disappointment in expert forecasting through the academic community's efforts. The leading universities and research centres provide the research and educational components, and private enterprises carry out the innovation component on a different scale [CSST, 2013].

Expectations about the potential of advanced manufacturing technologies for the global economy and for the transfer of promising production facilities to countries with highly developed technologies and educational systems, a positive business environment, and a high level of demand for new technologies are a significant incentive for governments of more developed countries to pay more attention to advanced manufacturing.

## Encouraging New Industrialization

The notion of localization, i.e. the placement of new industrial infrastructure near the development and design centres, research and design units, is closely linked with advanced manufacturing. Localization is common in US companies, as the US government is concerned about repatriation of production facilities. The country has lost a third of its industrial output as a result of moving production facilities overseas in the last decade. Meanwhile, just 35% of qualified engineers, 60% of R&D professionals and just 9% of workers are employed in the USA [CSST, 2013]. The drain of diverse highly qualified staff as a result of international relocation of the production facilities is regarded, in particular, as a threat to national security, one response to which is localization. At the same time, the government has stepped up its support to new institutions (regional 'hubs') engaged in development and prototyping of technologies and has quickly

Box 1. **US Government Policy in Advanced Manufacturing**

**June 2011.** President Barack Obama announced the Advanced Manufacturing Partnership (AMP), a multi-agency initiative with the participation of the US Departments of Defense, Energy, and Education as well as NASA, the National Science Foundation and the National Institute of Standards and Technology (NIST). AMP Steering Committee includes the heads of the top engineering universities, such as the Massachusetts Institute of Technology (MIT), University of California, Stanford University, University of Michigan and others, and the top management of major US companies (Caterpillar, Corning, Dow Chemicals, Ford, Honeywell, Intel, Johnson&Johnson, Northrop Grumman, Procter&Gamble, United Technologies).

**July 2012.** The President received a report on increasing the domestic competitive advantages in manufacturing technologies. It includes 16 recommendations divided into 3 groups: 1) promotion of innovations (including creation of new R&D consortiums); 2) personnel support (new educational programs and internships); 3) business environment improvements (tax reform, change in the technical regulation rules, enhancement of the trade and power engineering policy).

**August 2012.** The first specialized National Additive Manufacturing Innovation Institute (NAMII)<sup>1</sup> was set up.

It is a consortium amalgamation of more than 80 manufacturing companies, 9 research universities, 6 four-year colleges and 18 nonprofit organizations included into the Technological Belt of Ohio — Pennsylvania — West Virginia. USD 40m of financing comes from the industry and USD 30m from the government.

**January 2013.** The main parameters of the future National Network for Manufacturing Innovation (NNMI) were defined. It is intended to consolidate 15 institutes created as part of AMP.<sup>2</sup> The President requested USD 1 billion for funding of the network from the federal budget.

**May 2013.** The President announced the tender to set up three institutions of the following profile:

- Digital manufacturing and innovations in design;
- Manufacturing of light and modern metals;
- New generation in power electronics.

**October 2013.** Pooling the first experience, revision of 16 recommendations, their adjustment and detailed elaboration as part of AMP 2.0.

**January 2014.** The preferred bidders were approved for USD 1.5m to be allocated to each of them from the federal budget annually over 4 years. The tender to be held within a year to additionally set up four institutions — two to be supervised by the Department of Energy, and two by the Department of Defense — was announced.

Sources: [EOP, NSTC, AMNPO, 2013; White House, 2012, 2013a, 2013b].

implemented efforts to integrate them into the single network. The key facts and dates given in Box 1 demonstrate how promptly some particular decisions have been agreed upon and made, and also how rapidly the decisions have been incorporated into the operations of these institutions.

‘The Advanced Manufacturing Partnership (AMP) is not the first in a series of US governmental initiatives aimed at supporting ‘new industrialization’. Some technologies recognized as advanced now were federally supported in the past, but without major breakthroughs. For instance, the cyber physical systems and the Internet of things have been developed since 2006 but have not given rise to new manufacturing platforms. Out of the 108 projects supported by funding of between USD 500,000 to USD 1 million from the US National Science Foundation (NSF) since 2008, just one concerns industrial cyber physical systems [Forschungsunion, Acatech, 2013].

The new governmental initiative met with a mixed expert response. Some of them note, in particular, that repatriation of the manufacturing facilities to the USA is likely to boost labour efficiency but does not guarantee cost savings to major companies and growth in their securities quotations [Ratnikov, 2013].

The reasons why governments in many countries proceed to develop support efforts for advanced manufacturing are different. For instance, Germany thinks it is a global leader in plant engineering and construction, and its development is driven by growing competition on the part of the US, India, and China. Accordingly, government support focuses on enhancement of tools (procedural standardization, work algorithm improvement, trainings) and the regulatory environment, rather than on establishment of new en-

<sup>1</sup> Available at: [http://www.manufacturing.gov/nnmi\\_pilot\\_institute.html](http://www.manufacturing.gov/nnmi_pilot_institute.html), accessed 20.02.2014.

<sup>2</sup> Late in 2013, the possibility of expanding the network to include 45 institutions was discussed. Source: interview with MIT Vice Principal Martin Schmidt, taken by Irina Dezhina (Boston, 02.12.2013).



tities [Forschungsunion, Acatech, 2013]. Maintenance of global leadership in manufacturing equipment and expansion to new markets are chosen as strategic priorities. The idea is to use two global integration approaches for this purpose:

- Horizontal, via networks;
- Vertical, via related manufacturing systems.

Horizontal integration consists of linking IT systems used at different stages of the process flow and business planning. It implies the exchange of materials, energy and information, both within a company and between several companies (networks) [Forschungsunion, Acatech, 2013].

Vertical integration consists of connecting IT-systems from different hierarchy levels — process launch, monitoring, management, manufacturing, implementation, and corporate planning.

The ARTEMIS technological platform covering the eight areas of manufacturing technologies was established to promote R&D projects in the European Union. As part of this initiative, the Vision for Manufacturing 2.0 discussion document was drafted to define the investment priorities for the EU's new comprehensive program Horizon 2020 (2014/2020) [ARTEMIS, 2013].

China faces the challenge of rising labour costs; the development of advanced manufacturing is regarded as an instrument to address that challenge. Thus, the Chinese government's policy focuses on the technologies to decrease reliance on labour resources. In addition, the 12<sup>th</sup> five-year plan (for 2011–2015) aims to reduce foreign technology imports. The plan includes the use of subsidies, tax cuts and other financial instruments. In 2010, the first Chinese Internet of Things Centre was created, with a USD 117m budget to finance R&D, and the Area of the Internet of Things with 300 companies employing more than 70,000 persons was opened [Voigt, 2012].

## Development Priorities

Advanced manufacturing can be seen as a set of R&D fields identified with some particular precision (Table 1). For instance, US experts initially identified 11 key areas subdivided into 135 technologies based on crowd sourcing with the participation of the private sector only [NIST, 2013].

Despite a noticeable growth in the government's interest in new industrialization, Russia does not even have an indicative, agreed upon list of priorities in the field, let alone crowd sourcing of industrial companies [Gorbatova, 2014b]. The list of priorities is still adjusted within an ordinary budget cycle.<sup>3</sup> Some forecasts prove that the country has advanced manufacturing development potential; in particular, there have been significant advances in mathematical simulation and development of new materials. Several experts point to biomedicine and ICT as potential winners. According to the best-case scenario drafted by the Centre for Macroeconomic Analysis and Short-Term Forecasting (CMASF), the country's development prospects coincide with global trends in the core advanced manufacturing development areas, except for flexible manufacturing lines (where there is a 10-year lag behind global trends) and android robots (where Russia is not shown on the flow chart before 2030) (see Table 2).

## New Support Policy: US and UK Experience

Development of advanced manufacturing in foreign countries is largely integrated into their scientific and innovative policy. The most important points of emphasis are:

<sup>3</sup> According to the recent assignment given by the Russian President (assignment 8, Section 2), it is necessary to change the top priority areas of science, technology and equipment development in the Russian Federation and the list of critical technologies approved by Order of the Russian Federation President no 899 of July 7, 2011. Source: Russian President, List of Assignments to Implement the Message to the Federal Assembly, 27.12.2013. Available at: <http://www.kremlin.ru/assignments/20004>, accessed 14.02.2014.

Table 1. **Indicative advanced manufacturing priorities**

European Union	USA	China
<ul style="list-style-type: none"> <li>• advanced manufacturing</li> <li>• adaptive and smart manufacturing systems</li> <li>• digital, virtual and resource efficient manufacturing</li> <li>• mobile and cooperating enterprises (network manufacturing and agile production chains)</li> <li>• employee-centered manufacturing</li> <li>• consumer focused manufacturing</li> </ul>	<ul style="list-style-type: none"> <li>• sensors, measurement and flow control</li> <li>• modern materials design, synthesis and processing technologies</li> <li>• visualization, informatics and digital manufacturing technologies</li> <li>• sustainable manufacturing</li> <li>• industrial nano technologies</li> <li>• flexible electronics manufacturing</li> <li>• industrial biotechnologies and bioinformatics</li> <li>• 3D-printing</li> <li>• advanced manufacturing and test (quality assurance) equipment</li> <li>• industrial robotronics</li> <li>• advanced forming and connection technologies</li> </ul>	<ul style="list-style-type: none"> <li>• ICT –new generation industry</li> <li>• biological engineering</li> <li>• high-performance technologies and equipment</li> <li>• advanced materials</li> <li>• sensors</li> <li>• smart technologies</li> </ul>

Sources: [Factories of the Future PPP, 2012; White House, 2012; Knyaginina, 2013].

Table 2. **Manufacturing Technologies Development Prospects: Russia and the World**

Technology development horizon	Before 2015	Before 2020	Before 2030
Composite materials	World, Russia		
Manufacturing line flexibility improvement		World	Russia
3D-designing		World, Russia	
Internet of things			World, Russia
Industrial manufacturing of carbon nano tubes			World, Russia
Android robots			World

Source: [CMASF, 2013].

- 1) Use of technological priority directions as the benchmark that does not envisage mandatory financing of the outlined areas (technologies). The priorities are shaped not only through special appraisal or forecast studies but through crowd sourcing and serve rather to monitor subsequent development than to be the structural basis of future programs or created centres;
- 2) Creation of consortiums as one of the most common forms of advanced manufacturing support. These comprise companies, universities, regional authorities, service and consulting firms. Financial costs are partially covered by the federal budget, but the principal burden lies on the industry — co-financing by companies normally accounts for more than a half of the aggregate consortium budget. Consortiums have the following particular features:
  - Prototyping and output expansion as the top priority lines of business;
  - Network type of relationship;
  - Mandatory partnership with small businesses, science and educational institutions (in the USA, up to two-year colleges), links with the vocational colleges that meet the industry demand for personnel with new competences;
  - Ongoing concern for an autonomous existence and transition to self-financing after budget financing comes to an end.

The institutions created as part of the US National Manufacturing Innovations Chain, the Plants of the Future funded by EU through a public-private partnership [MIT, 2013] and the British Catapult Centres are examples of such consortiums;<sup>4</sup>

- 3) Combination of different instruments by insisting on flexibility and diversity in managerial decisions, giving up rigid arrangements and algorithms;

<sup>4</sup> Available at: <https://www.innovateuk.org/-/catapult-centres>, accessed 14.02.2014.

- 4) Permanent progress monitoring — diagnostic monitoring<sup>5</sup> — of the initiatives to detect any hurdles and to elaborate on possible improvements. The problems may be brought about by both the wrong choice of development tools and contractor errors. Diagnostic monitoring is different from more popular methods of effort efficiency measurement in that it assesses the degree of achievement of goals set earlier.

### Structural features of US. consortiums

Each institution in the established US National Network for Manufacturing Innovation is tasked with transformation into a regional ‘hub’ — the platform where fundamental research ‘melts’ into new products, and companies, universities, colleges and federal departments jointly invest into advanced manufacturing development. Such infrastructure also constitutes the unique ‘education factory’ — the foundation for training students and employees of all levels — as well as the chain of centres for collective use of equipment for small manufacturers that create, test and manufacture prototypes of new products and carry out pilot launches of process flows.

Operations of the institutions that are part of the described chain include, but are not limited to, the following kinds of activities:

- Applied research;
- Demonstration projects that reduce the costs and mitigate the risks related to commercialization of advanced technologies or that enable the problems industrial enterprises face to be resolved;
- Educational and training activities at all levels;
- Development of innovative methods and practices for integration of sales systems;
- Cooperation with small and medium industrial enterprises.

The last item is critical because the institutions are intended to assist in small business development in various forms, in particular, by ensuring access to the centres for collective equipment use, technical advice and assistance to the firms which may lack staff possessing the necessary competencies, and by providing information on advanced technologies. Finally, the institutions may deal with commercialization of their own startups.

The operations of all institutions are regional by nature, while the entire network of production innovations remains national in scale and significance. The idea is that essential technologies should be identified locally and should serve regional interests.<sup>6</sup> The possibility of using well-established tools (such as challenge grants provided by the State or funds on a tender basis) is discussed by experts in advanced manufacturing. This grant envisages that the money is not remitted until the set goals have been achieved, thus encouraging the recipients to achieve a particular result and look for new solutions. The innovation vouchers first tested in the Netherlands have proved to be efficient. They entitle the bearer to a certain sum of money for R&D, business plan development, et al. Small innovation companies, which often lack funds, may apply for vouchers to the appropriate department or fund. Then the firms that receive the vouchers turn to universities or centres capable of performing the required research, development or designing. The deliverable is paid for by the voucher, the value of which is made up for by the issuing agency later [Kiselev, Yakovleva, 2013].

In addition to the fundamental consortium operation principles, their *organizational setup* was subjected to thorough elaboration. Each consortium should have significant autonomy with respect to partner companies and an

<sup>5</sup> This term is borrowed from corporate managerial practices. It is the method of involved observation widely used in sociological surveys and which enables difficulties experienced by all process participants to be identified and ways to rectify the the problems found.

<sup>6</sup> Source: Mr. M. Schmidt, MIT Vice Principal, interviewed by I. Dezhina (Boston, USA, 02.12.2013).

## Box 2. SEMATECH Consortium Development Stages

SEMATECH nonprofit consortium initially included 14 major companies — semiconductor manufacturers (AMD, Freescale Semiconductor, Hewlett-Packard, IBM, Infineon Technologies, Intel, Panasonic, Philips, Samsung, Spansion, TSMC, Texas Instruments, and others) and was set up in 1986. It received funding on a parity basis from, on the one hand, the US Department of Energy (DOE) and DARPA Program for 5 years, and on the other hand, from industrial companies. The annual contribution of each of the parties came to USD 100m.

The consortium was tasked with studying advanced development trends in the semiconductor industry, development of the next-generation technologies, improvement of the expertise used in manufacturing of various products in this field, as well as enhancing competitiveness of the US industry to match the successes of Japanese manufacturers [SEMATECH, 1988]. SEMATECH uses not only its own laboratories transferred to it by the government but also participating companies' equipment.

After 9 years of operations (in 1996), the consortium actually abandoned the initial objectives and refocused on the global semiconductor industry. By resolution

of the board of directors, the participating companies rejected budget financing, in particular, due to problems with the rights to intellectual deliverables [NRC, 2003].

SEMATECH performance was most actively assessed in the early 1990s, spurred by the interest in efficiency of such public-private partnerships. No consensus was reached on SEMATECH performance. Negative feedback was received, in particular, from medium and small businesses, for which the consortium was a closed club of big chip manufacturers that had monopolized the technology developed within the club [Hoft, 2011]. The business community also indicated that SEMATECH did not have any breakthroughs that would have been impossible outside the consortium. However, the academic community gave positive feedback to the partnership touting it as a successful model of public-private cooperation [OECD, 2011]. It was calculated that, since SEMATECH's establishment, R&D costs for the new generation chips dropped by 30%.

The model was further disseminated in other sectors such as car making, construction, artificial intelligence based test-and-measurement systems, and environment-friendly industrial technologies.

independent board of directors comprising mostly of *representatives of companies*. To the extent possible, consortia should cooperate with each other, by exchanging resources, advanced experience and R&D deliverables. Financial models, the findings of forecast research and consortium membership tools should be discussed openly. Such transparency is necessitated by the fact that while consortia are not direct competitors and pursue different goals, they share a common mission to promote greater competitiveness of industrial manufacturing in the country.

Federal funding of USD 70–120m is allocated to each centre for 5 to 7 years. At the end of 2013, the possibility of extending this term to 10 years was discussed. At least half of each centre's budget is private investors' money. While federal funding is expected to be more significant in the first 2 to 3 years of operation, the share of private funding sources is planned to increase gradually in the future. In 7 to 10 years, all consortia must be *self-financed* through membership fees, income from intellectual property licensing, contractual research and other paid services.

The idea of the consortium network develops the model used to create SEMATECH, a consortium of semi-conductor companies (see Box 2). SEMATECH is usually viewed by politicians as a successful experience of 'steady' public-private partnership. The projects have different missions and goals, although their structure is generally the same. The question of whether the model is worth replicating under new conditions to develop advanced manufacturing is still open. The comparison of financial indicators only suggests that President Obama's current initiative, with a USD 70m budget of the pilot institution (see Box 1), is almost three times cheaper than SEMATECH's initial budget of the late 1980s, when the US dollar 'weight' was much bigger. One can hardly expect any breakthroughs, given such budget hurdles, unless the established centres are partially virtual and use first of all, the capacities of participating companies' and universities' laboratories.

With monitoring playing a key part in assessing efficiency of the consortia, the criteria by which one can judge the advantages and drawbacks of the new



Table 3. **USA: Key Indicators for Diagnostic Monitoring of Centre Development within AMP**

Positive impact on industrial development	Performance and efficiency of the centres	Network management efficiency	Stability of centres
<i>Number of new jobs</i>	<i>Number of new jobs</i>	Quantity and quality of relations between institutions	<i>Number of new jobs</i>
<i>Number of created startups</i>	<i>Number of created startups</i>	Income generated by institutions from the industry participation	Increment in the number of the industry participants, in particular, small companies
<i>Intra-institution partnerships</i>	<i>Intra-institution partnerships</i>	Number of patents/ intellectual property items in all the network institutions	Income from licensing intellectual property items
<i>Number of new technologies on the market</i>	<i>Number of new technologies on the market</i>	Learning lessons and dissemination of innovative approaches	New products and processes
Application of the methods developed by the industry in the institution	Participation of small businesses in institution operations		Number of repeated project co-investors
	Funding received from the industry and the federal budget		Income/cost ratio
	Number of projects brought from the study stage to the prototype		New export
	Number of students and industry personnel in the institution		
	Intellectual property portfolio		
	Number of licenses		
	Trade balance		
	Number of promotion efforts		

Source: [NIST, 2013].

entities become more important. The criteria currently discussed in the USA, in the course of elaboration of the created consortium network, are shown in Table 3. They are to be used within AMP to: (1) confirm or deny a favorable impact of the established centres on industrial development; (2) to assess their performance; (3) to evaluate the entity's efficiency in network management; and (4) to evaluate the centres' degree of stability [NIST, 2013]. Obviously, the proposed criteria partially overlap (we italicized these items in Table 3) and do not contain entirely new indicators. However, their mix, combined with quantitative and expert estimates, gives an idea of the nature of the existing problems and achievements.

### U.K. technical and innovative centres

The program to develop a network of technical/innovative Catapult centres in the UK was launched as early as 2010. Initiated by the government-created Technology Strategy Board, it envisages seven areas of focus for the new Catapult centres: high value manufacturing, cell-based treatment, offshore renewable energy, satellite software, integrated digital economy, cities of the future, and transportation systems.<sup>7</sup> The High Value Manufacturing Catapult was the first to be launched in October 2011. That Catapult centre was engaged in testing new technologies and systems before a decision on further investments into innovative projects was made. The Catapult included seven centres from different regions of the UK, specializing in different areas — from composite materials to 'process flow innovations'.<sup>8</sup> The organizational principles of the centres resemble those adopted in the USA, as part of AMP, namely:

- Multiple financing sources (national budget, industry, universities), with the planned total budget of GBP 140m for 6 years, provided that industry contributes half of the aggregate financing;

<sup>7</sup> Available at: <https://hvm.catapult.org.uk/history;jsessionid=A8D3A67DEB0ADB9955D8CE96E99A972B.2>, accessed 17.03.2014.

<sup>8</sup> Available at: <https://www.catapult.org.uk/high-value-manufacturing-catapult;jsessionid=1D85531FC73C5B43AE08089FE0587537.3>, accessed 05.04.2014.

- Prototyping and manufacturing of advanced products and services as business priorities.

The first deliverables of the High Value Manufacturing Catapult are already visible. It has created 700 new jobs and cooperated with almost 2,000 small and medium innovative companies involved in R&D.<sup>9</sup>

### Advanced Manufacturing Development Potential in Russia

The advanced manufacturing leaders regard Russia simply as a growing market for their new products in their strategic documents. Actually, since 2010, Russia has increased purchases of manufacturing equipment and is likely to maintain its status as one of the major importers in the near future. The aggregate demand of China, India and Russia for IT technologies accounts for 14% of global demand [Forschungsunion, Acatech, 2013].

In contemporary Russia, advanced manufacturing development is still governed as part of the country's industrial policy or local initiatives. For instance, the bulk of engineering projects that enjoy great attention [Labykin, 2014] are related to the creation of specialized centres at universities.<sup>10</sup> This approach is hardly justified as universities lack sufficient competencies to market manufactured products. Neither are the arrangements for implementing scientific developments discussed in Russia. At the same time, domestic companies have gained a certain amount of experience in creating advanced manufacturing consortia.

It is worth remembering that 2002 saw the launch of the program of innovative nationwide mega projects. Teams of scientists and industrialists were involved in these large-scale initiatives, which were jointly tasked with overcoming the biggest hurdles to greater competitiveness, in particular, reduction in production costs through resource savings. The mega projects were mostly selected based on a consensus between scientists and businessmen, and their non-budgetary financing was supposed to amount to at least 60%. Their work did not produce any systemic results; however, formal indicators recognized the mega projects as efficient in terms of use of the budget. Nevertheless, specialists of the National Research University — Higher School of Economics estimated the supported companies' efficiency to be lower than those participating in similar Western programs [Gokhberg *et al.*, 2011, p. 54].

This experience, in particular in project monitoring, may be useful for the development of advanced manufacturing. In addition, there are some examples of when diagnostic monitoring was successfully used to assess the effects of government incentives for corporate-academic cooperation [Dezhina, Simachev, 2013].

Technological platforms are a second potential tool. They help mobilize companies to discover the critical areas required to develop advanced manufacturing. In addition, as European practice suggests, technological platforms may lay the groundwork for setting up the consortia where major companies play the leading part.

Unfortunately, there are still more problems than achievements in the area under review for both science and innovations. First, according to the Thomson Reuters overview published in 2013, Russia is not included among the countries leading in the 100 most advanced research and development fields [King, Pendlebury, 2013]. Second, while developed nations have already shifted to multi-disciplinary research underlying many advanced manufacturing tech-

<sup>9</sup> Available at: <http://www.insidegovernment.co.uk/event-details/catapult-centres/202>, accessed 12.03.2014.

<sup>10</sup> This situation is partially explained by the data provided by the Ministry of Industry and Trade, according to which just 2% of Russian companies make use of engineering skills [Gorbatova, 2014a]. Based on the tender held in 2013, 11 winning universities were designated as engineering centre sites (11 projects were selected for implementation of the pilot projects aimed at creation and development of the engineering centres based on the leading technical universities). Available at: <http://минобрнауки.рф/новости/3719>, accessed 18.10.2013.

nologies [Balcerak, 2012], the importance of trans-disciplinarity is still at the discussion stage in Russia. That notion means blurring of distinctions between individual disciplines, combining different methodologies, the emergence of hybrid research areas, in particular, those areas helping to address complex technical and technological objectives.

The principles of budgetary support to technological R&D also need revision. Russia should move from funds allocation to management of current and expected deliverables, and from support to manufacturing of new prototypes to systemic technological upgrading [Knyaginina, 2013]. Advanced technologies account for less than 1.5% of funds of federal special purpose programs in civil aviation, marine equipment, electronic component base and pharmaceuticals.<sup>11</sup> Finally, the current ‘innovation enforcement’ policy only has negative implications due to the lack of economic demand and enforcement. For instance, the development and implementation of innovative development programs by state-run companies often evolve into attempts to pass off marketing projects as innovations [Expert-RA, 2012]. Irrespective of economic interest, companies seek to report properly to the state, without their involvement in significant innovations. As participants of the Open Government’s strategic session noted in March 2014 the typical features of state-run companies ‘forced’ to innovate, just like their supervisory authorities, remain their closed nature and lack of transparency. Enterprises prefer investments for production upgrading rather than for the development of advanced technologies, which means they therefore lag behind foreign competitors and have reduced overall efficiency.

In our opinion, one should not disregard the experience of borrowing from Western models of recent public policy as they can offer useful lessons. Localization of new forms of support to the last stages of the development and design of industrial technologies in Russia may be simplified through understanding the local specifics and knowledge of the ‘sore spots’ in the national economy. The above mentioned diagnostic monitoring, as part of the consortium creation strategy, may be an experience worth borrowing. The customization development potential may also be found in a feature of Russian innovations whereby unique products are manufactured more successfully than mass industrial products [Auzan, 2013].

Developed and several developing nations use a broad range of tools for promoting the emergence and dissemination of advanced manufacturing: from amendments to various economic regulations to supporting new science-and-industry forms of cooperation. In such a way it is possible to build up an integral support system, while in contrast Russia is only introducing isolated measures. We still have time and recent foreign experiences, together with the innovative entrepreneurship infrastructure taking shape in Russia, which may enable us to connect with the global context and find our niche globally. In such a connection, two organizational scenarios are possible: first, where we establish territorial and industrial consortia and second, where we implement end-to-end R&D programs to ensure leadership in particular areas.

### **Particular Features of Consortium Creation: Instead of a Conclusion**

In our opinion, the new advanced manufacturing development tools should be coordinated above all with the infrastructure projects and development programs for certain technical fields that Russia has already implemented. They concern the government support system which covers many fields from fundamental research to manufacturing of developmental prototypes and industrial technological re-equipment.

The creation of an institutional core comprising of consortia of scientific organizations and companies is of critical importance for advanced manufacturing. Such consortia may be established as part of a specialized program of scien-

<sup>11</sup> Federal Special Purpose Programs: Development of Civil Aviation Equipment in Russia in 2002–2010 up to 2015; Development of Civil Marine Equipment in 2009–2016, Development of Electronic Component Base and Radioelectronics in 2008–2015, Development of Pharmaceutical and Medical Industry in Russia to 2020 and Beyond.

tific and educational support to advanced manufacturing development, which would cover the pre-competitive research stage. Its implementation may begin with pilot projects coordinated with the Ministry of Industry and Trade sub-programs to support competitiveness of technological fields such as composition materials, machine tool building and robototronics. Engineering centres that re-equip manufacturing facilities with new generation technologies acquire increased significance here.

Consortia may be created in places with existing efficient research infrastructure, such as universities, shared equipment use centres, technological clusters, and territorial structures (clusters, industrial clusters et al.) that are managed jointly with industrial companies. As shown above, operations of consortia might cover analysis of the research base; corporate demand assessment; applied research and prototyping; participation in research projects on the basis of international cooperation; personnel training; and further training (such as short-term courses, master programs and post-graduate programs in promising areas).

The consortium may comprise of several laboratories that implement, together with industry, three- to five-year programs of applied research and personnel training and involve students and post-graduate students in research. Co-financing by companies, with a gradual shift to self-sufficiency, is an important pre-requisite for the laboratories' operations. Such an approach would help to coordinate the government personnel and technological policies, which the previous paradigm did not ensure. Naturally, this strategy is not the only one: other options exist.

We argue that a systemic strategy for developing new technologies is a critical part of Russian research and development policy because of the many economic incentives brought by advanced technologies. Their implementation leads to favorable conditions for manufacturing decentralization, reduction of market entry barriers to small industrial companies, outsourcing, stimulation of small and medium business activity, and the creation of high-tech jobs in the regions. This exerts even greater pressure on major industrial corporations, thus improving the competitive environment. F

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# Foresight in Civil Shipbuilding — 2030

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**Foresight studies of future markets and technologies enable various scenarios for the shipbuilding industry to be identified.**

**Innovative scenarios assume a shift from mass production to small-scale or even single-unit niche production under diversified demand. This should be accompanied by active promotion of competition not only in shipbuilding but in related industries too.**

**Comparative analysis of scenarios shows that active government policies to support the production of high-technology vessels will generate multiplier effects and strengthen the competitiveness of the Russian economy.**

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## Keywords

shipbuilding; emerging markets; innovative technologies; Foresight; technological forecasting; global challenges; scenarios

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Shipbuilding is an economic sector that has high scientific, technological and production potential and is capable of generating a significant impact on the development of technology in related industries. As a result, key maritime states around the world pay particular attention to the creation and development of innovative technologies in the shipbuilding industry.

Foresight has confirmed its effectiveness as a long-term forecasting instrument for scientific, technological and economic development in the industry as it allows analysts to take into account a complex array of factors influencing market supply and demand alongside current technological trends [Georghiou *et al*, 2008; Gokhberg, Sokolov, 2013; Saritas *et al*, 2013; Haegeman *et al*, 2013]. This article seeks to outline the future of the shipbuilding industry in the period up to 2030 based on an assessment of the current state of the global and domestic shipbuilding and ship repair markets and a forecast of changes with account of contextual factors.

The prospects for scientific and technological development in the domestic civil shipbuilding and ship repair industries have been viewed in the context of global, national and inter-industry challenges, trends, driving forces and constraints. This study of inter-industry interaction has enabled us to highlight the synergetic effects brought about by the application of technological innovations from other economic industries.

## Methodology

In technology forecasting practice technology-oriented (technology push) and market-oriented (market pull) approaches are typically adopted. While the first derives from an analysis of research developments with some potential for practical application and innovative technologies and high-tech products and services based on these developments [Kim *et al*, 2009; Lee *et al*, 2007; Lichtenthaler, 2008], the second is focused on studying the factors linked to demand for innovative products and certain technologies used in their production [Albright, Kappel, 2003; Daim, Oliver, 2008; Holmes, Ferrill, 2005; Lee *et al*, 2009]. Foresight studies in any sector of the economy presuppose a synthesis of these approaches, combining the scope for application of prospective products with their production opportunities, which in turn is heavily dependent on the results of scientific research and development (R&D). This is of particular importance for high-tech industries, the specific nature of which directly shapes the mechanism to couple supply with demand [Dodgson, 2000; Wells *et al*, 2004; Karasev, Vishnevskiy, 2013; Caetano, Amaral, 2011]. It is primarily a question of the high value of scientific and technological offerings (human, material, technical, information and financial resources) and the weak predictability of future demand for R&D and new technologies: its segments, dynamics, volume, etc.

The combination of methods used to analyse the development of high-tech sectors of the economy has enabled us to give a comprehensive assessment of factors affecting the scientific, technological, production and market potential of specific innovative products in the civil shipbuilding industry and to formulate substantiated recommendations on a system of priorities for each link of the technological chain. A large group of experts has been involved in the study, selected on the basis of strict qualifying criteria. Among them are members of the research community, industry, government bodies and foreign specialists from leading nations in the shipbuilding industry.

During the five stages of the Foresight study (Table 1), the potential competitiveness of certain groups of innovative products was assessed from a demand perspective, and segments and clusters of innovative technologies were identified. To this end, a knowledge base was created after classifying and sorting the conclusions drawn by many specialist studies on innovative development in the shipbuilding industry and related sectors, including various strategies, programmes and forecasts developed in Russia and abroad [Minpromtorg, 2013; European Commission, 2012; European Commission, 2009; Marine Institute, 2006; Norwegian Agency for Development Cooperation, 2010; Boelens *et al*, 2005; Giovacchini, Sersic, 2012; and others].

Table 1. Stages of the Foresight study into the development of the shipbuilding industry

Stages	Description
1	Creation of the knowledge base: more than 90 Russian and foreign sources of various types were analysed.
2	Analysis of the current state of and trends in the development of the global shipbuilding industry; <ul style="list-style-type: none"> <li>• discussion of current developmental trends in the shipbuilding industry in Russia and abroad;</li> <li>• study of external environmental factors shaping economic demand for various shipbuilding products;</li> <li>• outline of the inherent challenges facing the industry.</li> </ul>
3	Study of the factors affecting future demand for innovative products: <ul style="list-style-type: none"> <li>• description of the typical groups of consumers in each segment;</li> <li>• analysis of the developmental prospects of existing demand segments;</li> <li>• identification of potential niches in the market;</li> <li>• discussion of factors affecting changes in long-term demand and the potential to satisfy demand through innovation.</li> </ul>
4	Identification of technological priorities and opportunities in the Russian shipbuilding industry <ul style="list-style-type: none"> <li>• analysis of the potential competitiveness of certain groups of innovative products in the identified demand segments;</li> <li>• discussion of the risks, barriers and constraints of innovative development;</li> <li>• SWOT-analysis of the strengths (S) and weaknesses (W) of manufacturers in the shipbuilding industry and their potential development opportunities (O) and threats (T);</li> <li>• drawing up a list of prospective technologies and products.</li> </ul>
5	Modelling of alternative developmental trajectories in the domestic shipbuilding industry using a scenario method: <ul style="list-style-type: none"> <li>• discussion of key factors of uncertainty and forks (bifurcation points) where changes in trajectory could occur;</li> <li>• development of possible industry development scenarios;</li> <li>• definition of characteristics and conditions for the realisation of these scenarios;</li> <li>• formulation of expected results.</li> </ul>

Source: HSE ISSEK.

Any substantiated forecast of developmental prospects in the shipbuilding industry will be based on external environmental influences, including global trends in social and economic development. Since the industry is heavily dependent on global phenomena such as the environment, energy, demography, food, transport and technological change, one of the key sources shaping the future of the shipbuilding industry which forms the basis for this analysis is the concept of ‘grand challenges’ [European Commission, 2010a; European Commission, 2010b]. These relate to, among other things, urbanisation, labour migration and changes to the population age structure (ageing). Major global trends include the spread of electrical data transfer networks, the increasing significance of bio-, micro- and nano-technologies, the rapid growth of the intellectual services sector, and the growing influence of international organisations, etc. The response to these factors must come from forward-looking developments and the implementation of new technologies and products to satisfy our rapidly changing needs. Challenges that are negative (threats) and positive (opportunities) are already manifesting themselves today. They serve as harbingers of future large-scale shifts in the shipbuilding industry, set national and industry-specific trends and predetermine priorities for scientific, technological and innovative development.

The high degree of uncertainty defines the long-term prospects for innovative development. Therefore, for the purposes of our study, different variants of the developmental course in the civil shipbuilding industry have been explored using a scenario-based method. During the modelling of these alternative trajectories, we have taken into account, above all, uncertainty factors and forks (bifurcation points) where changes in trajectory could take place [Ogilvy, 2002; Godet, 2001; Kennedy *et al*, 2003]. Based on the results of the study, possible scenarios for the development of the shipbuilding industry have been identified, together with their characteristics and the conditions for their realisation, the attendant challenges and risks, as well as the results which are achievable in the long-term under the ‘scenario’ priorities system.

There is extensive global experience in the elaboration of scenarios for the development of the shipbuilding industry. In this regard, the study Global Scenarios of Shipping in 2030 [Wartsila, 2010]<sup>1</sup> proposes three potential scenarios for the period up to 2030: ‘Rough Seas’, ‘Yellow River’ and ‘Open Oceans’, all developed taking into account changes in external factors. According to the first of these scenarios, limited resources and growth in social and inter-ethnic tension are cited as key factors in the development of the shipbuilding industry. The second scenario proposes the emer-

<sup>1</sup> This study was carried out by the Finnish company Wartsila, a company specialising in the production of ship propulsion systems, power plants, propeller mechanisms, ship guidance systems and other equipment.



gence of China as a global and economic leader, including in the shipbuilding industry. In the third scenario, global corporations govern the global economy. To study external factors, the influence on the future of the shipbuilding industry is presented in the useful 2006 study of alternative scenarios for the future of the maritime ecosystem by the British Centre for Environment, Fisheries and Aquaculture Science. The report examines the varying development of certain segments of the shipbuilding industry using wild card events (events which are extremely unlikely to occur but could have a radical change in the external environment) [Pinnegar *et al*, 2006].

This Foresight study and the developmental scenarios of the domestic shipbuilding industry created as a result of the research have enabled us to identify certain priorities for the innovative process, to express the coherence of these findings and to uncover certain correlations. We selected integral prospective fields in the shipbuilding industry that have the potential to complete the entire innovative cycle — from R&D to commercialisation of the end product. Based on the scenarios, we have formulated certain intrinsic challenges facing the industry: positive — new opportunities to implement innovative products; and negative — fixing the ‘bottlenecks’ in the innovation system and identifying the attendant risks, constraints and barriers.

### The global shipbuilding industry: key trends and global challenges

According to surveyed experts, a decisive factor in the current state of the global shipbuilding market is the overproduction crisis and the steady rise in capacity backed by domestic demand from manufacturing nations. The capacity of traditional exporters therefore remains unused. Changes in the markets, including at local level, for freight traffic, labour, and certain product types (oil, timber and others) play a significant role in this.

Today, there are approximately 560 shipyards around the world capable of building a ship within one year with a total tonnage of 55–60 million CGT (compensated gross tonnage).<sup>2</sup> However, there is a core of around 166 shipyards which provide 85% of the global shipbuilding industry’s output (in 2011, their workload did not exceed 85%). To assess annual workforce productivity, the ratio of the combined tonnage of the ships produced in one year (in CGT) to the number of employees working at the shipyard is taken into account. Thus, in Japan this figure is approximately 180 CGT per person, South Korea — 145, Germany — 75, the remaining EU countries — 40, and in Russia only 20 CGT per person [Minpromtorg, 2013].

The changing development of global shipping suggests a transformation in its structure. Over recent years the specific weight and tonnage of bulk shipping has changed significantly around the world, largely due to heavy-tonnage ships. In the period 2009–2013, the proportion of bulk shipping (by deadweight tonnage) around the world increased from 37% to 44%, while the specific weight of tanker shipping reduced from 31% to 28%. At the same time, the proportion of ships used to transport liquid chemicals and liquefied gases and special dry-cargo ships rose, while the specific weight of general dry-cargo and traditional refrigerator vessels fell.

Positive trends in the development of global shipping are being buoyed by encouraging shifts in international trade. Nevertheless, data on global maritime transport and changes in cargo shipping for 2010–2011 confirm a persistent imbalance between supply and demand on freight markets.

An analysis of the regional structure of the global shipbuilding and repair market as well as the specific advantages of leading international companies has identified the success factors of certain leading nations in the sector (Fig. 1).

As we can see from Figure 1, European companies, traditionally seen as occupying strong positions on high-tech product markets, have considerably lost

<sup>2</sup> An indicator of the amount of work required to build a ship. Calculated by multiplying the carrying capacity of the ship by a coefficient determined according to the ship’s specific type and size.

Figure 1. Results of a SWOT analysis of the leading players on the shipbuilding market

South Korea		Japan	
Strengths	Weaknesses	Strengths	Weaknesses
<ul style="list-style-type: none"> <li>• qualified workforce</li> <li>• economies of scale</li> <li>• developed extractive industry</li> <li>• high buyer confidence</li> <li>• developed, high quality shipbuilding technologies</li> <li>• high labour productivity</li> <li>• short production cycle</li> </ul>	<ul style="list-style-type: none"> <li>• insufficiently developed inland shipping</li> <li>• high workforce costs</li> <li>• low business diversification</li> <li>• insufficient development of the financial market</li> <li>• lack of base technologies in the cruise ship and sea facilities segments</li> </ul>	<ul style="list-style-type: none"> <li>• high level of innovative activity</li> <li>• presence of a large number of small- and medium-sized innovative businesses</li> <li>• high quality of sea equipment</li> <li>• stable links between shipyards and ship equipment manufacturers</li> <li>• stable employment conditions</li> <li>• specialisation in niche markets</li> </ul>	<ul style="list-style-type: none"> <li>• high expenditure (including wages and steel prices)</li> <li>• potential difficulties protecting knowledge (in particular among small- and medium-sized businesses)</li> <li>• shortage of qualified specialists</li> </ul>
Opportunities	Threats	Opportunities	Threats
<ul style="list-style-type: none"> <li>• low raw material prices</li> <li>• depreciation of the Korean currency</li> </ul>	<ul style="list-style-type: none"> <li>• growth in the Chinese economy and consolidation of its position on the shipbuilding industry</li> <li>• instability on the global shipbuilding market</li> <li>• low demand for shipbuilding products</li> <li>• surplus output</li> </ul>	<ul style="list-style-type: none"> <li>• continuous innovation</li> <li>• environmental awareness of the shipbuilding industry</li> <li>• active transport policy (environmentally-friendly transport, improved transport services quality)</li> <li>• increased transport standards requirements</li> </ul>	<ul style="list-style-type: none"> <li>• intensification of marine clusters</li> <li>• consolidation of competitors' positions on the market</li> <li>• lack of workforce and ageing workforce</li> <li>• price-based competition in the light of the economic crisis</li> </ul>
China		European Union	
Strengths	Weaknesses	Strengths	Weaknesses
<ul style="list-style-type: none"> <li>• low labour costs</li> <li>• sufficient steel supplies</li> <li>• significant government support</li> </ul>	<ul style="list-style-type: none"> <li>• insufficient development of shipbuilding design and technologies</li> <li>• lack of production of key components in the country</li> </ul>	<ul style="list-style-type: none"> <li>• highly-qualified workforce</li> <li>• high level of technological development of the shipbuilding industry</li> <li>• government support and protectionism</li> <li>• high labour productivity</li> </ul>	<ul style="list-style-type: none"> <li>• high production costs</li> <li>• dominance of internal orders over external</li> </ul>
Opportunities	Threats	Opportunities	Threats
<ul style="list-style-type: none"> <li>• growth in demand for sea and river transport to ship iron ore, coal, grain, construction materials and other bulk freight</li> </ul>	<ul style="list-style-type: none"> <li>• lack of qualified specialists</li> <li>• fluctuations in national currency exchange rates</li> <li>• surplus output</li> <li>• fall in productivity</li> </ul>	<ul style="list-style-type: none"> <li>• development of competitive advantages</li> </ul>	<ul style="list-style-type: none"> <li>• loss of position on the market due to lower production costs among competitors</li> <li>• collapse in global prices</li> </ul>

Source: HSE ISSEK.

their competitive advantages due to high production costs. On the contrary, strong state support and cooperation with Japanese and South Korean companies have allowed China to quickly take a leading position. The success of Korean manufacturers is down to developed infrastructure, high quality products and the professionalism of their engineering and technical staff. Small business innovation and niche specialisation have allowed Japan to hold on to a significant market share which, however, is gradually shrinking under the pressure of high production costs. However, all leading nations in the shipbuilding industry are now engaging in large-scale R&D investment.

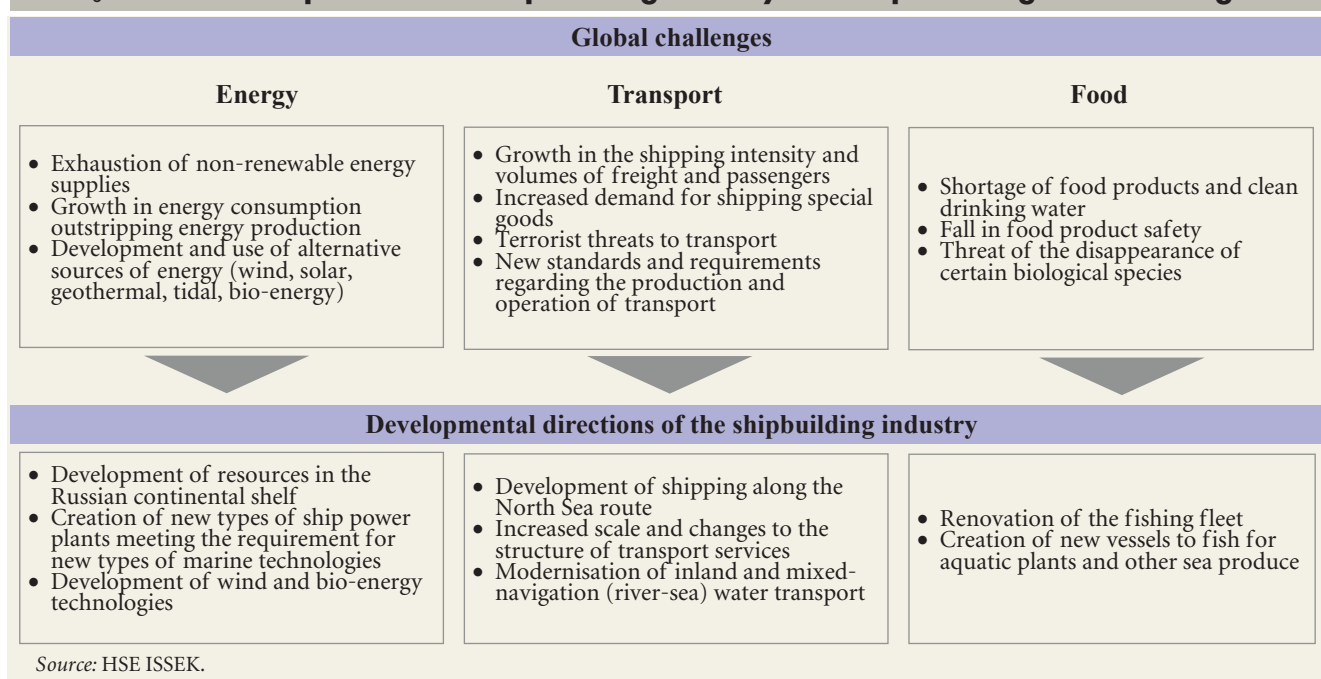
### Global challenges

An important stage of this study was the analysis of global challenges in various industries (energy, transport, food, etc.) Together, these challenges define the prospective directions of the shipbuilding industry. Thus, the gradual exhaustion of traditional non-renewable sources of energy calls for active development of resources in the continental shelf; the intensity and volume of freight transport attach considerable importance to the development of shipping along the North Sea routes; and the shortage of food products and clean drinking water is giving rise to a resurgence in fishing fleet activity (Fig. 2).

### Technological priorities

National Foresight studies together with the strategies of leading Russian and foreign shipbuilding companies allow an overview of the innovative technologies and high-tech products which manufacturers consider to be their priorities to be compiled and compared with the challenges and driving forces behind innovative development and inter-industry interaction (technology push).

Figure 2. The development of the shipbuilding industry as a response to global challenges



Over 400 technologies and products were consolidated into 11 groups (thematic industries):

- ecology and environmental protection;
- engines and mechanisms;
- ship construction;
- new materials and processing technologies;
- information technology and automated systems;
- navigation and telecommunications;
- energy and energy saving;
- safety and security;
- steering and control;
- ship life cycle technologies;
- production technologies.

Despite the discrepancy in technological priorities across countries, in the future the shipbuilding industry will call for new production technologies and improved ship, engine, machinery and mechanism designs (Fig. 3).

It is clear from Figure 3 that the strategic interests of Japanese companies are concentrated around new types of ship engines and mechanisms, energy-saving technologies, new materials and improved environmental credentials of products in the industry. China's priorities are primarily linked to new production technologies, ship designs and safety. Korean specialists expressed an heightened interest in information technologies and automated systems.

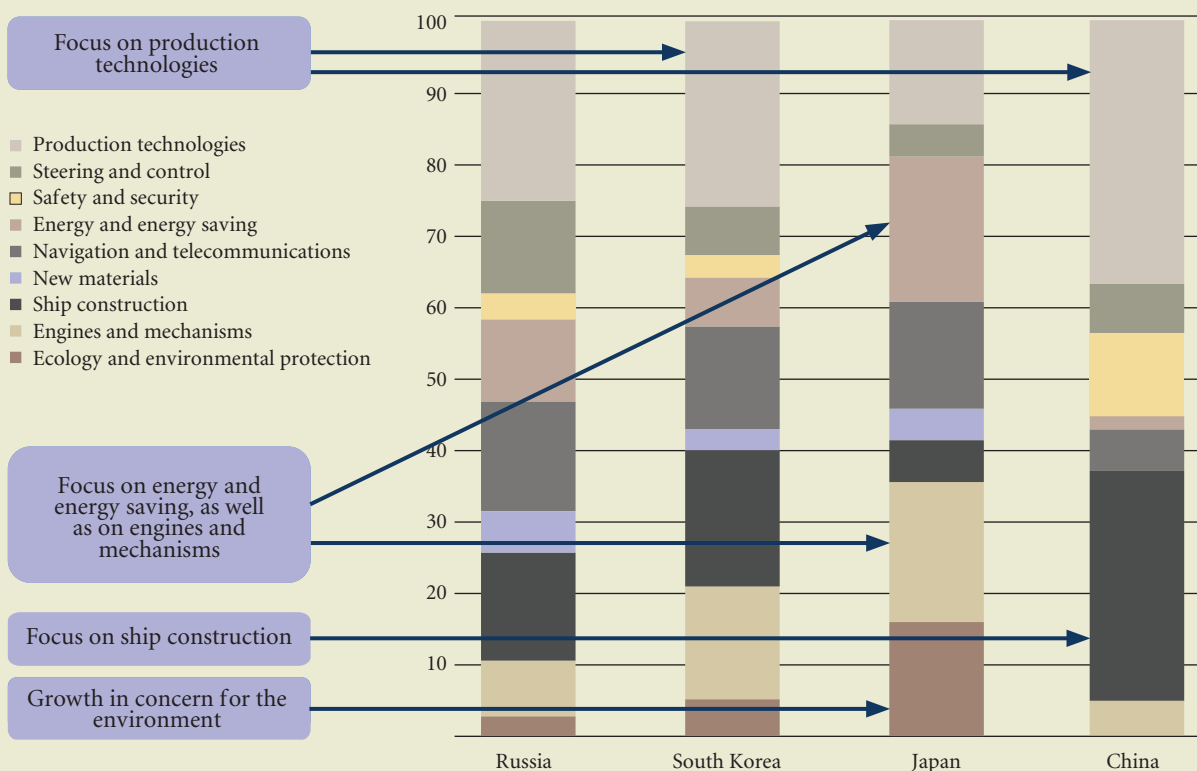
### The Russian shipbuilding industry: opportunities

Historically, a significant proportion of domestic machinery, electronics and devices for ships have been developed and produced within Russia. The industry has more than 200 businesses working on maritime and river technology, building and repairing ships with displacements of up to five thousand tonnes [Minpromtorg, 2013]. Shipbuilders collaborate with more than 2000 businesses supplying component end products used in the production process. In this regard, shipbuilders are one of the main domestic consumers of metal products which makes the metal working industry dependent on the outlook of the Russian shipbuilding industry.

#### Maritime cargo shipping

The Russian economy needs steady growth in freight turnover from waterborne transport — both maritime and inland. The proportion of Russian ex-

Figure 3. **National technological priorities (percentage of total number of technologies)**



Source: HSE ISSEK. based on national Foresight study material

port/import cargo as a percentage of global maritime cargo transportation in 2011 was approximately 6%. However, with control over almost 1,400 vessels with a total dead-weight of 19.6 million tonnes (1,067 vessels with a dead-weight of 5.2 million tonnes flying the Russian flag and 351 vessels with a dead-weight of 14.4 million tonnes — or approximately 75% — flying a foreign flag), Russia’s share of the global shipping industry is 1.56%, which is about 16<sup>th</sup> or 17<sup>th</sup> in the world rankings. Based on the capacity of ships flying the national flag, Russia’s share is 1.61% (27<sup>th</sup> globally). The average age of Russian vessels is 22.9 years, whereas for foreign ships it is 8.2 [Minpromtorg, 2013].

Achieving 50% of Russian foreign trade cargo operations using domestic transport (at present, it is approximately 6% for maritime transport) and 100% through national terminal capacity (currently about 80%) is a strategic objective.

Experts predict that in future, the transportation of products from Russian hydrocarbon deposits will increase significantly. This will be primarily in the Arctic shelf and in the coastal region, and new directions will be identified for the development of traditional (‘conventional’) shipping.

### Inland water-borne transport

10–15% of freight shipments and approximately 5% of passenger journeys in Russia take place using inland water-borne transport. Russia’s key advantage lies in low costs, but the main problem is the seasonality of operations. In the past decade, inland water-borne routes have been used with growing intensity. In 2010–2012 there was a surge in demand from Russian shipping companies for inland and mixed navigation cargo vessels, however, the opportunities for manufacturers held back growth in shipments.

Russian water-borne passenger (cruise) transport is characterised by above-average wear and tear and obsolescence. The age of the majority of vessels built almost exclusively abroad (in Germany, Czechoslovakia, Austria and other countries) is 40–50 years. With the advent of high-speed new ships based on a dynamic means of keeping afloat (hydrofoils and hovercraft) Russia had significant technological advantages and has to a considerable extent maintained this potential to the present



day. High-speed passenger shipping could play a significant role in solving the issue of transport accessibility, a relatively critical problem facing many regions across the country. This segment of the market is of little interest to foreign shipbuilders, which opens up greater prospects for their Russian colleagues. High volumes and off-the-shelf solutions serve as security for effective technological solutions in the industry and productive inter-plant collaboration to manufacture components.

According to expert assessments, in the next 8–10 years the combined order portfolio for inland water-borne transport vessels could exceed 100 billion roubles. Engineers, producers and those operating inland and mixed navigation ships face the following scientific and technical issues:

- maximising the load-bearing capacity of ships amid constraints on their berthing;
- extending freight navigation during the spring and autumn with acceptable costs (new technologies to break initial ice forms and highly fractured ice);
- developing inland water-borne logistics.

### Equipment to develop the continental shelf

Sea-based shelf deposit technologies have been in development since the start of the 20<sup>th</sup> century. In the second half of the century, various classes of maritime structures appeared to enable oil and gas extraction, and by the early 1980s, there were three groups of off-shore technologies: drilling platforms, production platforms and supply vessels.

Today, the ocean shelf supports approximately 50% of global hydrocarbon extraction. At the same time, shallow continental and coastal deposits are nearing depletion, which increases the importance of deep deposits (2,000–3,000 m) hundreds of kilometres away from the coastline.

Changes to natural and climate conditions lead to new demands of maritime oil and gas extraction facilities. While the first sea-based facilities were situated in the Caspian Sea and the Persian Gulf, and later across the Gulf of Mexico and the North and Norwegian seas, future international projects are looking to develop deposits in the Barents and Kara seas.

Vast mineral supplies, chiefly raw hydrocarbons, can be found in the Russian continental shelf. The largest and most promising portion of these supplies is concentrated in the seas and on the coast of the Arctic Ocean where the extreme natural and climatic conditions (primarily, ice) is unprecedented. The experience of Russian companies working on the Sakhalin Island, North Caspian and Barents Sea shelves is clearly not adequate. The poorly developed coastal infrastructure and special environmental demands on companies operating in the region create further difficulties when developing the Arctic deposits. In addition, we cannot count on importing technology. Foreign oil and gas extraction and operating companies involved in Russian continental shelf projects have shown their inability to independently work on the designs of sea-based technical facilities and to implement a work cycle to prepare deposits for working in icy conditions.

These problems call for the design and implementation of entirely new Russian sea technologies: innovative technological solutions to use in underwater icy conditions. Innovations are required both in terms of the extraction and liquefaction of gas in small volumes and the shipment and transportation of the extracted raw material (for example, Shell's pilot project Prelude on the Australian continental shelf to extract, liquefy and ship by sea 3.6 million tonnes of gas per year).

Technological developments are essential both to convert gas into methanol, then to shift the technology platform to a new footing, as well as to devise alternative ways to transport it (in gas-hydrate form or compressed). The required innovations described entail increased safety demands regarding the transportation of hydrocarbons: the combustion heat of liquefied gas transported by a 150,000 m<sup>3</sup> methane carrier vessel reaches the equivalent of 100 kt of TNT, which is 5–6 times greater than the energy yield of the atom bomb dropped on Hiroshima.

The significant advantages of developing the promising Russian continental shelf may well result in the use of certain new technological solutions. First, this would involve the production of synthetic fuel from gas based on Fischer-Tropsch synthesis, which, according to specialists, will come to be advantageous once a certain price

has been reached for hydrocarbons. In this regard, Shell built a plant to produce synthetic fuel in Qatar in 2007. Then in 2011, several companies started to develop Compact GTL equipment enabling them to produce synthetic fuel on a sea-based platform directly at the gas extraction site. Experts also commend this potential use of underwater vessels for prospecting and underwater extraction facilities to develop deposits in regions with difficult icy conditions.

The evidence presented in this section leads us to suggest two trends linked to the development of the continental shelf which could have the greatest impact on the Russian shipbuilding industry in the next 20–30 years:

- growth in the processing depth of formation products from sea-based platforms followed by ship transportation to demand regions;
- gradual transition to fully integrated underwater (under ice) technologies to develop shelf deposits — from prospecting to processing.

### Commercial shipping

Support for Russian commercial shipping comes from the need to guarantee the food security of the country. Unfortunately, over the last 15 years there has been a steady ageing and reduction in the size of vessel fleets in the industry.

The Russian fishing fleet is made up of approximately 2,000 ships with various purposes. More than 80% of them are operated beyond their standard service life. They are not only ineffective, but also do not meet modern safety standards. To meet the required fish and seafood catches, the maximum service life of vessels is forever increasing.

By 2020, the number of vessels could shrink by almost two-fold relative to the current level, with this mainly affecting medium- and high-tonnage vessels the most. In addition, the country's objective demand for commercial ships in the period up to 2025 is valued at approximately 180 large and medium and at least 220 small vessels of various profiles, making a total worth in excess of 170 billion roubles. A significant proportion of domestic demand for civil shipbuilding can be satisfied by Russian shipbuilders.

The key priorities for industry members are:

- to develop their scientific and technological stock to manufacture highly cost-effective, competitive ships;
- to modernise and build commercial, auxiliary and transport vessels, and special equipment to extract and process water-based bio-resources;
- to improve the financial and economic conditions surrounding the construction and lease of ships, in particular, by subsidising loan and lease payment interest rates;
- to reduce the price of ships;
- to transfer and implement foreign civil shipbuilding technologies.

Modernising commercial shipping will make it possible to broaden the food base through maximising the effective use of sea bio-resources. While currently the bulk of catches are in the economic zone in the seas around Russia, long-term there needs to be renewed expeditionary fishing in distant regions of the ocean, requiring the development and construction of appropriate vessels.

### Potential market niches

The potential for development in the shipbuilding industry is linked to the choice of priority market niches to sell products. These market segments must show high demand for various classes of vessels with diverse functional purposes, but they must also respond to certain consumer demands (*market pull*).

The shipbuilding market is traditionally divided into five segments:

- passenger and freight transport;
- extraction and processing of sea-based bio-resources;
- scientific research;
- development and working of mineral deposits;
- technical and support work and services.

Each segment is influenced by the macro-economic factors described above. Thus, GDP growth, increases in global trading, steel production, higher labour productiv-

ity in the industry, and other factors all have a positive effect on these segments. In contrast, factors such as rising fuel and steel prices, and currency risks can have a negative impact on the situation in certain market niches in the shipbuilding industry.

The Russian shipbuilding industry faces three priority challenges, which will shape the course of its development over the coming decades:

- effective development of the North Sea route;
- effective and environmentally friendly development of Pacific Ocean resources, primarily bio-resources and hydrocarbons on the Russian continental shelf (with a full life cycle involving prospecting, extraction, and transportation of raw materials and finished products to regions where demand is);
- expansion of the transport network – guaranteeing access to inland waterways for freight and passenger vessels and extending the navigation season.

The solution to these tasks presupposes the development and construction of ships and maritime equipment which are capable of operating under difficult icy conditions on inland waterways, along the North Sea shipping routes, and in regions where the Arctic shelf is being developed. These are still essentially unoccupied niches on the global shipbuilding market, free from the presence (competition) of foreign companies. The range of such vessels and maritime equipment could include, but is not limited to, drilling and operating platforms, shipping terminals, various types of ships to extract hydrocarbons, ice-breakers, tugboats, ships with a high ice class (including tankers and gas carriers), scientific research vessels (to study the oil and gas potential of the continental shelf, provide hydrometeorological support, and monitor the environment), and environmental safety vessels.

All the ships and water-borne facilities listed above are some of the most high-tech and knowledge-intensive products in the shipbuilding industry. Russian research and design-and-engineering organisations had a significant lead in this field, one which is only poorly exploited in practice. In the worst case scenario, the existing competitive advantages could be lost irretrievably amid increased efforts from many foreign shipbuilding companies seeking involvement in projects linked to the development of the Russian Arctic.

Taking into account the current production structure and technological organisation of the domestic shipbuilding industry, fully securing these niches for Russian companies not only satisfies the country's production potential, but also the current objectives of the national economy. The achievement of this goal is one step along the path towards the creation of new production output capable of producing high-tonnage Arctic navigation vessels and large sea platforms.

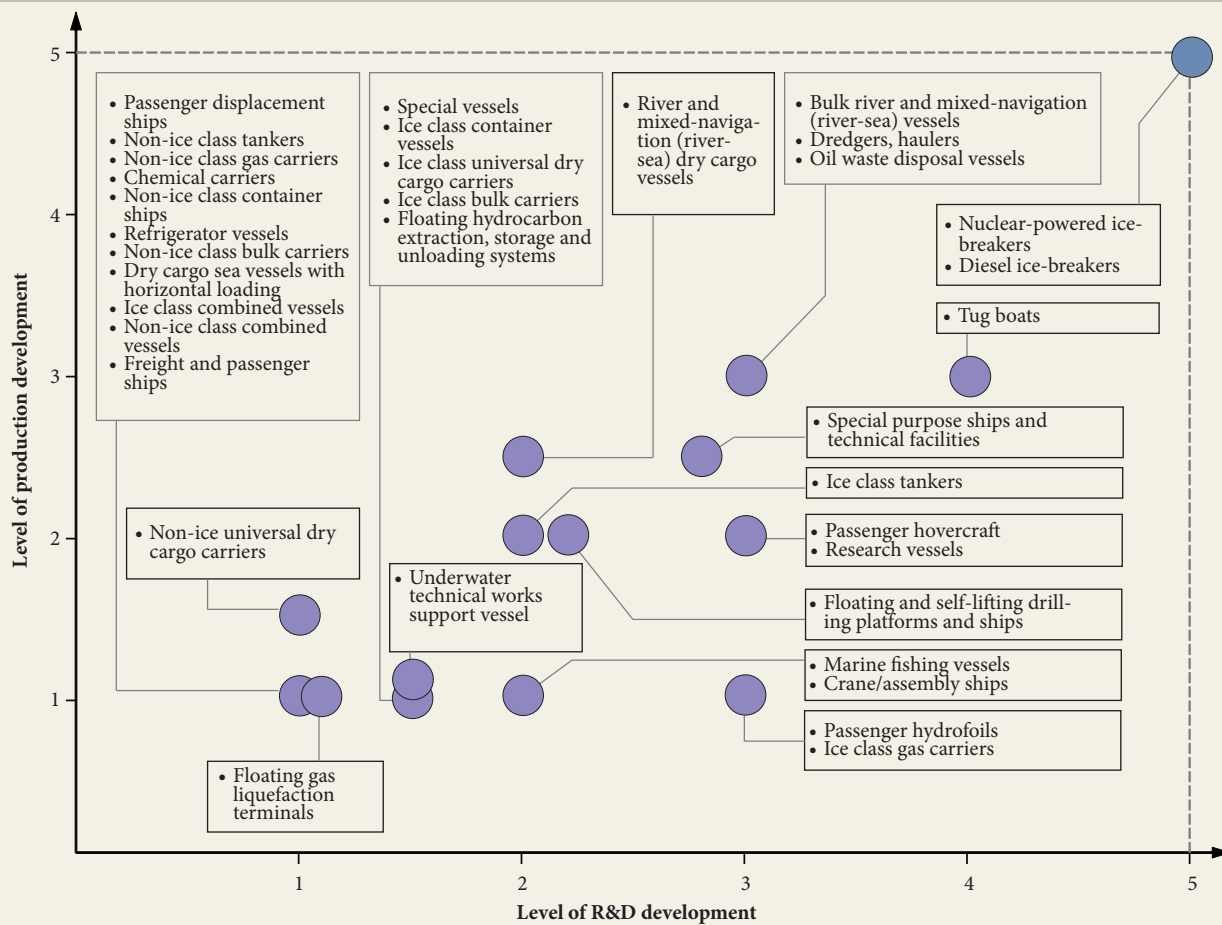
Based on experts' assessments, we carried out an analysis of the market potential of products from the Russian shipbuilding industry (Fig. 4).

### Barriers, risks and opportunities

Objectively, the long production cycle and colossal capital-output ratio of production in civil shipbuilding cause high levels of concentration and significant barriers to entry. These are problems not only for manufacturers, but also consumers who are faced with high prices for products and unfavourable lending conditions, which, in turn, make the customer dependent on the financial infrastructure. The credit term is five years at best, covers a maximum of 60% of the cost of the ship, and rates are several times higher than abroad. One of the consequences of this situation is the lack of competition between buyers: attracting investment on the global financial markets to place an order for ships is only possible for the very largest ship owning companies. Moreover, the lending terms are less attractive than they are for their global competitors, who are able to take advantage of favourable financial conditions and governmental support in their own countries.

Focusing on niche products would place the Russian shipbuilding industry in a new competitive environment and allow the industry to transition from batch production with strict pricing policies to filling highly specialised orders. Local market niche players would no longer have to engage in direct and harsh competitive struggles. However, breaking onto new markets is not possible without corresponding legislation and the introduction of effective economic mechanisms; the absence of

Figure 4. Level of competitiveness of certain types of shipbuilding products\*



\* Calculated on the basis of a survey of exports, using ratings on a scale from 1 to 5:

- 1 — significantly below foreign standards;
- 2 — slightly below foreign standards;
- 3 — on a par with similar foreign products;
- 4 — slightly above foreign standards;
- 5 — significantly above foreign standards.

Source: HSE ISSEK.

these factors would expose companies to serious additional risks which, briefly, include:

1. The displacement of civil shipbuilding from the global and Russian market, leading both to direct budgetary losses and to further dependence on foreign carriers with their increasing presence in the North Sea shipping zone and their penetration into the inland river network;
2. International legal disputes over the development of Arctic hydrocarbon deposits;
3. The possible reduction in state support for the shipbuilding industry and weakened protectionism due to the Russian Federation joining the WTO;
4. The shortage of qualified workers in the industry;
5. The worsening financial and economic position of consumers, the change in consumer priorities, and the configuration of the entire sales market in the industry;
6. A reduction in potential investor activity in the face of an unfavourable investment climate;
7. Complications in the financial position of developers and manufacturers of shipbuilding products, etc.

To assess the dynamics of the shipbuilding industry and determine its growth areas, we carried out a SWOT analysis showing the range of opportunities for development in the industry and the internal and external obstacles (Fig. 5).



The challenges currently facing today's shipbuilding industry are systemic in nature. Some of them can partly be solved on a federal level with the help of industry-wide programmes. However, to achieve the set targets, such measures are not enough insofar as the construction of innovative vessels requires equipment and materials produced by associated sectors of the industry. There needs to be an entire complex of integrated solutions that aims to harmonise the activities of all companies manufacturing the sea and river technologies required in the near and distant future.

## Innovative development scenarios in the Russian shipbuilding industry

By analysing the current situation of the Russian shipbuilding market, we have been able to identify the main challenges facing the industry and affecting its future development:

- the structural disparity of the shipbuilding industry;
- the reduced competitiveness of Russian products on the global market;
- imperfect legislation and financial infrastructure;
- the need for state support.

To build the scenario matrix, experts chose two critical factors to plot the developmental course of the civil shipbuilding industry in Russia: innovative activity against the development of the national economy. In the method we adopted, each of these factors was assigned two values: low or high 'innovative activity' and unfavourable or favourable 'development of the national economy.' The combination of these values and factors allowed four potential scenarios for the development of the industry to be identified (Fig. 6).

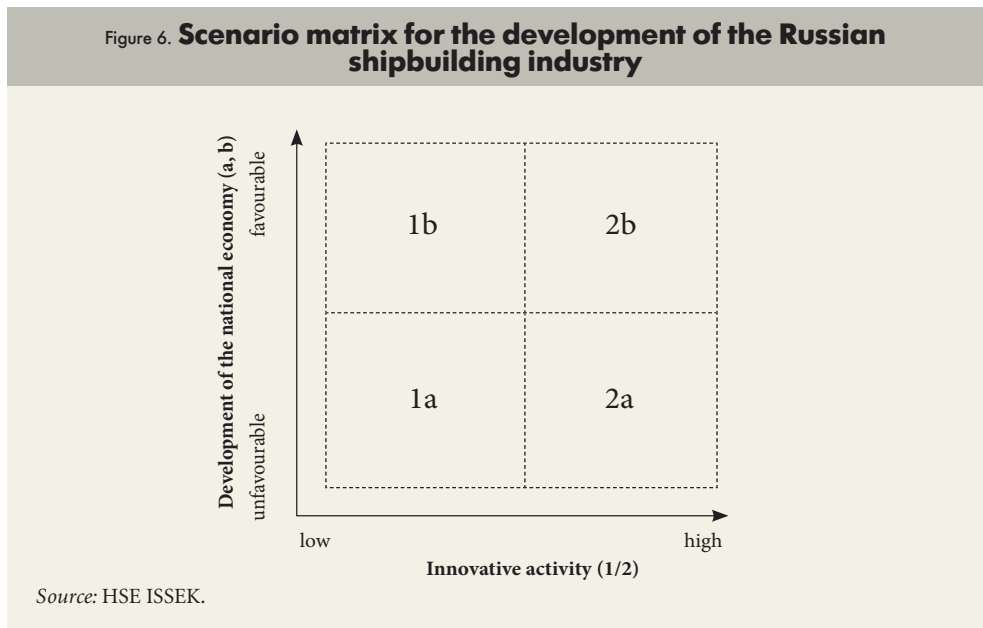
The inertial scenarios for the development of the shipbuilding industry (1a, 1b) result from the failure to adopt measures that aim to eliminate the barriers to the industry's development and ignore the possible risks. The pessimistic inertial sce-

Figure 5. **SWOT analysis of the domestic shipbuilding industry**

Strengths	Weaknesses
<ul style="list-style-type: none"> <li>• Low cost price of inland water transport journeys</li> <li>• Partial retention of technological potential since the days of the USSR</li> <li>• Presence of government industry development programmes</li> <li>• Presence of technologies to develop sea-based shelf deposits</li> </ul> <p style="text-align: center; background-color: #e6f2ff;">Key market development reserves are linked to the development and creation of ships and marine technologies for operation in the Arctic region</p>	<ul style="list-style-type: none"> <li>• Inadequate funding</li> <li>• Technological backwardness in the civil shipbuilding industry</li> <li>• Low production efficiency, labour productivity, product competitiveness</li> <li>• Low rate of renewal of key production resources</li> <li>• Lack of qualified personnel</li> <li>• Low profitability on Arctic deposits</li> <li>• Lack of competition in labour conditions compared with other economic sectors</li> <li>• Depreciation of inland waterway infrastructure</li> <li>• Lag behind modern international standards regarding a number of ship environmental parameters</li> <li>• High cost of ship construction, lack of investor incentives</li> <li>• Long repair times or servicing for transport vehicles</li> <li>• Lack of domestic technological base in several areas, lack of development of the element base, insufficient quality of domestic construction and expendable materials</li> <li>• High cost of prototyping when developing transport vehicles</li> <li>• Lack of production output to build transport vessels with a deadweight of over 70-80 thousand tonnes (full displacement over 100,000 tonnes)</li> <li>• Lack of financial and tax incentives for shipbuilding businesses</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>• Growth in water transport freight turnover</li> <li>• Expansion of shipping into the Spring and Autumn</li> <li>• Solving the problem of poor access in certain territories across the country using high-speed passenger vessels</li> <li>• Emergence of new segments of demand for shipbuilding products</li> <li>• Development of international transport corridor systems</li> <li>• Development of recreation zones in seaside cities</li> <li>• Development of tourism and growth in demand for river travel</li> <li>• Development of technologies to work shelf deposits</li> <li>• Development of high-speed water transport</li> <li>• Growth in business investment in ocean research and development of marine biotechnologies</li> <li>• Development of new resource-saving technologies and technologies to process water bio-resources</li> <li>• Development of new trade regions and facilities</li> <li>• Development of targeted programmes and strategies on a national and international level geared towards developing the industry (including programmes to develop bio-technologies)</li> <li>• Implementation of projects to improve sea bio-resource extraction and processing quality</li> </ul>	<ul style="list-style-type: none"> <li>• Expected financial crises and economic instability</li> <li>• Sharp fall in defence R&amp;D in the 1990s-2000s</li> <li>• Ageing regulatory framework for ship design</li> <li>• Improvement in competitors' positions on the market</li> </ul>

Source: HSE ISSEK.

Figure 6. **Scenario matrix for the development of the Russian shipbuilding industry**



nario (1a) assumes an unstable economic situation in Russia and globally, a lack of funding opportunities for long-term projects, an overall drop in production levels and, as a result, a fall in demand for sea transport. The optimistic inertial scenario (1b) is characterised by a favourable economic situation in Russia, good conditions on the hydrocarbons market, an improved investment climate and resulting growth in investment in ship production and shipyard construction. However, the absence of any required changes in the legislative framework and the continuing poor financial infrastructure in the scenario hold back the forecast growth rates of the industry and hinder the solution of its structural problems.

The innovative scenarios (2a, 2b) assume full implementation of state support programmes for the shipbuilding industry, sufficient funding for R&D, as well as gradual changes to the production structure, increasing the proportion of commercial output.

The combination of characteristics from each of these scenarios affects the future outlook of the industry as a whole (Table 2).

**Inertial scenarios**

According to the *pessimistic inertial scenario*, not a single modern shipyard will be built in Russia, and the introduction of innovative technologies into the shipbuilding industry will be put off. The lack of investment in R&D into new production and ship operation methods has particularly acute consequences.

The main demand segments for domestic shipbuilding products under this developmental model of events comes from freight traffic (river- and mixed-navigation) and the extraction and processing of marine bio-resources. In addition, non-self-propelled and self-propelled water-borne facilities will be in demand to operate on inland waterways and high-speed vessels.

Under the *optimistic inertial scenario*, as noted above, we can expect a fall in production growth rates and an intensification of structural imbalances. The continuation of the existing funding principles for the shipbuilding industry will place Russian manufacturers in a poor situation compared with global competitors. A substantial chunk of funds goes on purchasing equipment using imported components without any comparable products in Russia.

The development of the industry along one of these scenarios will follow demand from consumers in market segments such as freight shipping, the extraction and processing of marine bio-resources, and the development and working of Arctic mineral deposits. There will be demand for small high-speed vessels, ships for inland waterways and sophisticated commercial ships (research vessels, ice-breakers, support and technical ships). 70-80% of demand for inland water transport may be satisfied, whereas only 50-60% of demand for sophisticated commercial ships is likely to be.

Table 2. **Characteristics of development scenarios for the shipbuilding industry in Russia**

Characteristics	Development scenarios			
	Inertial		Innovative	
	pessimistic	optimistic	pessimistic	optimistic
Ratio of commercial to military production	Predominance of military production and defence orders	Predominance of military production and defence orders	Balance between commercial and military production in total industry output	Balance between commercial and military production in total industry output
Competitiveness of production	Low	Average	Average	High
Legislative framework	Poor legislative framework, propensity for corruption, legal barriers to business development	Poor legislative framework, propensity for corruption	Elimination of legislative defects	Elimination of legislative defects
State policy in the shipbuilding industry	Curtailement or suspension of state programmes	Partial curtailement or suspension of state programmes	Continuation of state programmes	Continuation of state programmes
Financial infrastructure	Weak	Weak	Existence of funding and lending mechanisms	Existence of funding and lending mechanisms
Global trade and GDP	Fall	Rise	Fall	Rise
Oil price	50 US dollars/barrel	from 100 US dollars/barrel	50 US dollars/barrel	from 100 US dollars/barrel

Source: HSE ISSEK.

The inertial scenarios are fraught with a number of negative consequences for the Russian shipbuilding industry, including:

- the loss of some of the most important technologies, which could significantly complicate the implementation of the government programme in the shipbuilding industry;
- a reduction in the number of ships built due to increases in production costs and time;
- loss of position on the global shipbuilding market.

Table 3 shows the likely changes in the industry under inertial developmental models.

### Innovative scenarios

The *pessimistic innovative scenario* presupposes active government support for the shipbuilding industry and the formation of effective financial infrastructure. These conditions will make it possible to construct a modern shipyard to build commercial vessels with a fall in economic indicators and some deficit in financial resources. It will give rise to prerequisites to transition onto an innovative developmental path for the industry using modern technologies. In particular, there is forecast to be an expansion in the number of relevant research projects.

Under this scenario, there will be demand for a wider range of products than in previous variants in market segments such as freight shipping, the extraction and processing of marine bio-resources, the development and working of Arctic deposits,

Table 3. **Key shipbuilding indicators under inertial scenarios**

	2012	Pessimistic			Optimistic		
		2015	2020	2030	2015	2020	2030
Production volume ( <i>billions of roubles</i> )	90	200	160	100	250	180	100
Share of the global military shipbuilding market (%)	12	11	10	< 10	12	13	14
Share of the civil shipbuilding market (%)	0.4	0.3	0.3	0.4	0.5	1	2
Construction of inland water-borne transport (share of required level, %)	4	30	30–40	30–40	30–40	50	70
Construction of sophisticated commercial ships (share of required level, %)	0.5	2–3	5–7	10	5–10	20–30	50–60
Share of Russian foreign trade cargo base shipped by Russian transport (by sea-based transport, %)	6	6	6	6	7	8	10

Source: HSE ISSEK.

Table 4. Key innovative scenario indicators for shipbuilding industry development

	2012	Pessimistic			Optimistic		
		2015	2020	2030	2015	2020	2030
Production volume ( <i>billions of rubles</i> )	90	350	500	650	350	500	700
Share of the global military equipment market (%)	12	12	14	15	12	15	> 15
Share of the global commercial equipment market (%)	0.3	0.5	1	1.5	0.6	1.5	2.5
Construction of inland water-borne transport (share of required level, %)	4	10–20	30–40	70–80	10–20	40–50	100
Construction of sophisticated commercial ships (share of required level, %)	≈ 0.5	10–15	30–35	70–75	10–20	40–50	100
Construction of large sea platforms (share of required level, %)	≈ 0.5	5–10	20–30	40–50	5–10	20–30	50–60
Construction of high-tonnage maritime ships (share of required level, %)	≈ 0.5	1–2	5–10	10–20	5–10	20–30	40–50
Share of Russian foreign trade cargo base shipped by Russian transport (by sea-based transport, %)	6	15	20–30	50	15	30	50

Source: HSE ISSEK.

scientific research, and technical and support work and services. It is expected that Russian manufacturers will succeed in satisfying 70%–80% of demand for inland waterway vessels. As for the construction of sophisticated commercial vessels (research ships, ice-breakers, platform supply vessels, support and technical ships), this figure will reach 100% of the required volume, for sea platforms the same figure will be around 40%–50%, and for high-tonnage vessels — 10%–20%.

*The optimistic innovative scenario* assumes an effective government policy under favourable economic conditions, propelling the Russian shipbuilding industry into a new round of development, increasing its investment appeal and improving its technological infrastructure. Such a turn of events would enable the industry to construct several modern shipyards to build commercial vessels, intensively introduce innovative technologies during production, and increase R&D. Exports of commercial vessels could reach 600–800 million US dollars per year, with export figures for military ships around 2.3–3.0 billion US dollars.

Instead of supporting the construction of an entire range of ships, the optimistic innovative scenario envisages pinpoint initiatives for small-scale or even single-unit niche production. It calls on existing horizontally integrated structures to be re-organised into clusters for niche production to act as drivers of growth in the industry.

The transition to an innovative scenario requires active support for competition in associated industries in the form of clusters. The multiplier effects generated by the production of high-tech special-purpose ships will consolidate the competitive position of companies at all points of the production chain. Manufacturers can direct their attention towards various demand segments — passenger (river) and freight shipping, the extraction and processing of marine bio-resources, the development and working of Arctic deposits, scientific research, and technical and support work. Demand for inland water transport, in particular, and for sophisticated sea vessels will be met in full; demand for sea platforms with innovative processing and drilling technologies will be satisfied at the level of 50%–60%; for sea shipping vessels, only 40%–50% of demand will be met. This means that 2%–2.5% of the global civil shipbuilding market can be gained.

Likely indicators for the development of the shipbuilding industry with its transition to an innovative developmental path are shown in Table 4.

The realisation of these innovative scenarios will lead to the development of not only domestic competition by involving highly competitive types of activity in shipbuilding clusters, but also to foreign competition thanks to the Russian shipbuilding industry's shift to monopolistic (rather than price-based) competition where it has, or could have, clear advantages. Unlike in the inertial scenarios, state investment would be targeted only at areas where financing from the state is of utmost necessity (notably, to areas of growth for a future cluster hub).



## Conclusion

As a result of applying Foresight methods in our study, we have identified the priority objectives facing the shipbuilding industry. Finding solutions to certain challenges will reduce the negative impact of global factors and make it possible to harness the competitive advantages of the domestic shipbuilding industry; advantages which can be gained by realising both existing and new opportunities globally. The analysis of global trends and the discussion of sector-specific priorities for the Russian shipbuilding industry have allowed us to present a prospective product line taking into account the external challenges that may have an effect on consumption structure and consumer preferences.

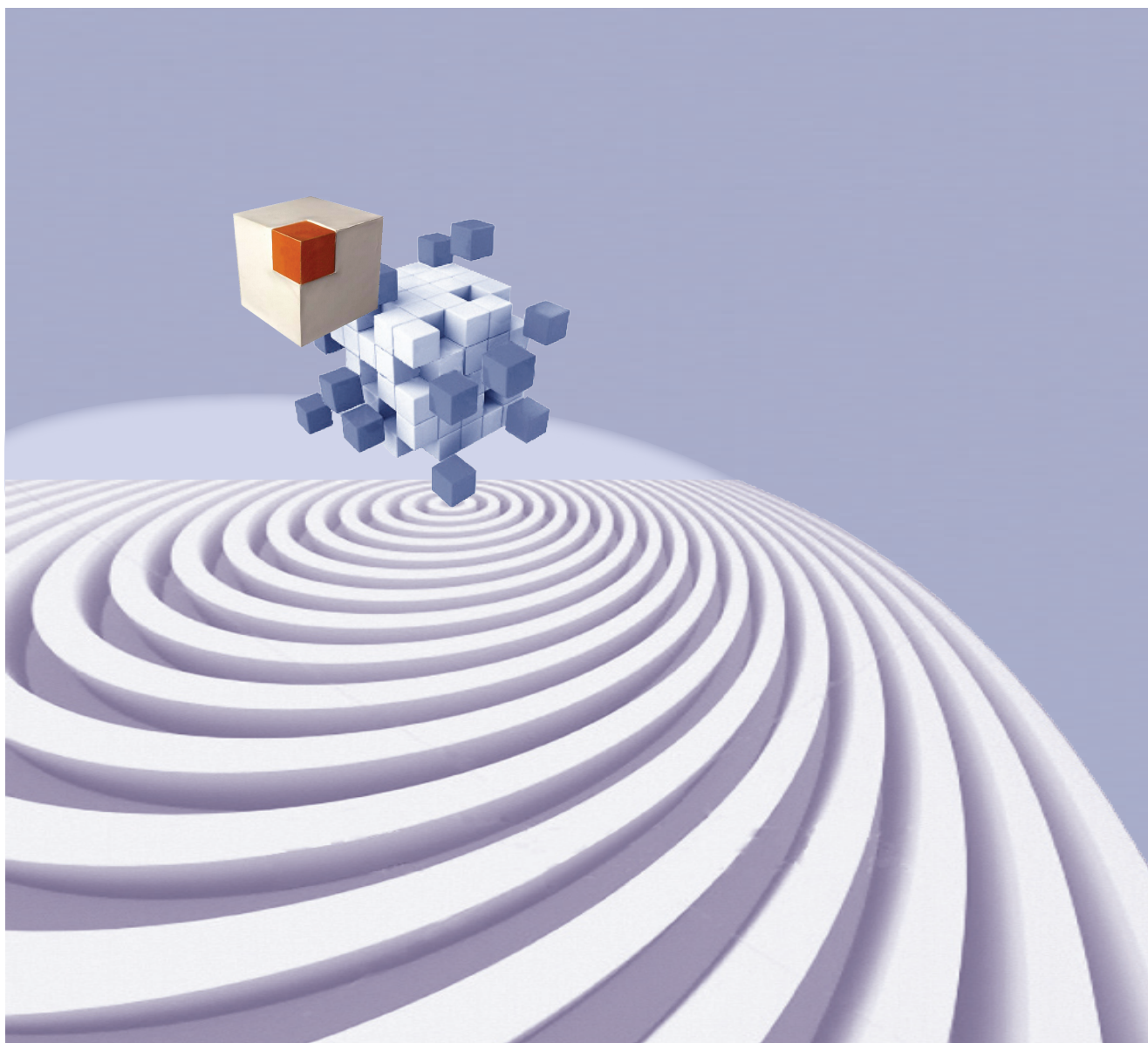
An assessment of the factors shaping the scientific, technological, production and market potential of specific innovative products could be beneficial when elaborating a set of substantiated recommendations linked to a detailed system of priorities at each stage of the technological chain. Our analysis showed that in leading shipbuilding nations of the world a substantial proportion of R&D is aimed at developing production technologies and improving ship, engine, equipment and machinery designs.

The comparison of the possible developmental scenarios for the shipbuilding industry for the period up to 2030, taking into account the parameters and impact of these scenarios, showed that the production of high-tech vessels against the backdrop of active government policy in the civil shipbuilding industry (the innovative scenario) will give rise to multiplier effects and will consolidate the competitiveness of the Russian economy. ■

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# STI Foresight in Brazil

Cristiano Cagnin



Globally, advanced countries and institutions emphasise Foresight studies that create spaces for structured dialogue with a focus on systemic or transformative innovation. Aligned with the coordination of societal actors, foresight processes of that kind aim to better enable innovation systems to address common challenges. In doing so, foresight activities become more relevant and have greater impacts in decision-making processes.

The analysis of the evolution of Foresight in Brazil presented in this paper shows a greater role of such studies in formulating science, technology and innovation policy. Foresight projects carried out by the Brazilian Center for Strategic Studies and Management in Science, Technology and Innovation (CGEE) raise new strategic questions that should be investigated and addressed to reorient the Brazilian National Innovation System.

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## Keywords

Foresight;  
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Brazil;  
Foresight generations;  
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disruptive innovations

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In essence, the objective of foresight is to shape spaces for structured dialogue that fosters engagement, creativity and reflection, both individual and collective. Hence, the aim is to use the future as a trigger to spark imagination and expand our understanding of the present through structured conversation to collectively imagine the future and make choices in the present [Miller, 2007; Miller, 2011a; Miller, 2011b].

Various methods, tools, instruments and techniques are used to structure dialogue and shape possible future developments. However, understanding the relationship between context, content and approach is critical in the design and implementation of a foresight process [Cagnin *et al.*, 2008]. Moreover, expected results and associated impacts, both tangible and intangible, should be defined from the outset [Da Costa *et al.*, 2008].

Foresight approaches have evolved over **successive generations or phases**, which are not mutually exclusive [Johnston, 2002, 2007; Cuhls, 2003; Georghiou, 2001, 2007]. Briefly, these phases are: i) technology forecasting or internal dynamics of technology with expert participation; ii) the interaction between technology and markets, with participation from across the academic-industry nexus; iii) the interaction between markets and social actors, with a user-oriented perspective and broader societal participation; iv) a disseminated role in the science and innovation system, with multiple organisations carrying out exercises fit for individual purposes but coordinated with other activities; and v) a mix of distributed exercises focused on either structures or actors within the Science, Technology and Innovation (STI) system, or on the scientific/technological dimensions of broader social and economic issues and challenges.

Foresight practice occurs mainly in **two ‘modes’**, although a combination of both is possible and becoming commonplace. In ‘mode 1’ the aim is to improve or optimise the existing system [Weber, 2006; Eriksson, Weber, 2006; Havas *et al.*, 2007]. ‘Mode 2’, on the other hand, focuses on debating and promoting fundamental changes of established paradigms [Da Costa *et al.*, 2008]. At the same time, a number of **principles** guide foresight work (adapted from [Keenan *et al.*, 2006]): i) a medium to long term perspective; ii) active participation of stakeholders; iii) the use of evidence and informed opinions, thus combining interpretative and creative approaches; iv) coordination; v) multi-disciplinarity; and vi) action-orientation.

Globally, advanced countries and institutions practice a combination of phases four and five as well as ‘modes’ 1 and 2. This takes place routinely and with close attention to the six principles mentioned above. The aim is to make foresight activities more relevant and have greater impact in the decision making process, such as in the design and implementation of public policy. The Center for Strategic Studies and Management in Science Technology and Innovation (CGEE) is, therefore, aiming to advance in this direction rather than concentrating efforts only in the first and third generations and in ‘mode 1’.

## Foresight Evolution

The post-industrial revolution caused many social and technological transformations and saw a sense of preoccupation towards the future become more widespread. During that time, attention was on improving decision processes and public debate, and on anticipating the trends and long-term implications of short-term decisions.

In the 19<sup>th</sup> and 20<sup>th</sup> centuries classical economists centred their analyses on the future of capitalist economies. The early 1900s saw the establishment of the principles of trend extrapolation and social indicators. The term foresight appeared in a speech delivered by H. G. Wells for the Royal Institution of Great Britain in 1902 entitled ‘The discovery of the future’, which argued that the future could be known or understood scientifically [Wells, 1913]. The first systematic methods of experts’ analysis and the first simulation studies were developed in the second half of the 20<sup>th</sup> century (e.g. Delphi and cross impact analysis).

In the 1930s and 1940s, when the effects of the Great Depression were very pronounced, a new world order looked at science and technology (S&T) as a means to recovery. H.G. Wells published ‘An Experiment in Prophecy’ in which



he anticipated the world in 2000: he predicted modern transport dispersing people from cities to suburbs, moral restrictions that were diminished due to sexual freedom, and the formation of the EU (e.g. [Wells, 1901a; Wells, 1901b]). In 1932, Wells also defended the institutionalisation of what he called the ‘departments and professors of foresight.’ In 1945, a committee had the task to look ahead 20 years to envision the evolution of the aviation sector and identify the steps needed for the US Air Force to get there. Future studies initiated towards the second half of the 1940s when institutions like the think tank RAND Corporation (Research ANd Development Corporation) and SRI International (SRI) were created to develop long-term planning by analysing systematic trends for military purposes soon after the WWII.

Following the end of WWII and the start of the Cold War, during the 1950s and 1960s, the focus of future studies turned to anticipate future technologies, mainly for defence objectives. RAND and SRI used system analysis and developed games theory, and scenario and Delphi methods. The focus was on S&T and engineering, developed by and for military application and big corporations. A limited number of experts and futurists were involved in these activities, and the main methods used were Delphi, scenarios, brainstorming and expert panels. Foresight’s conceptual and methodological basis developed in this period. Hence, this is considered to be the birth of modern foresight practice based on operational research efficiency and aiming at deliberate interventions to direct desired change. Foresight practitioners were mainly concerned about probabilistic analysis of what may happen in the future based on an extrapolation of past events (i.e. forecasting). Key works in this period include ‘The art of conjecture’ [de Jouvenel, 1963] and ‘Inventing the future’ [Gabor, 1964]. In 1966, the first future-oriented university course was developed in the US by Alvin Toffler at The New School (New York).

During the 1970s, the world began to understand the limits of forecasting due to the oil crises and the failure of predictions such as ‘Limits to Growth’ [Meadows et al., 1972] and ‘Catastrophe or New Society?’ [Bariloche Foundation, 1976]. Unpredictable events led to a wider understanding of the uncertainty and complexity of global systems.

Forecasting in the 1970s came to be less deterministic, to ‘accept’ that the future is not a mere extension of the past, and to realise that discontinuities do occur. Japan uses forecasting methods about the future of S&T to inform its policies, including in its analysis of social and economic needs as well as advances in S&T. A number of activities started worldwide such as the Futuribles Project in France, the Committee for the Next 30 Years in the UK, and the Hudson Institute in the US (a spin-off of RAND). The EU developed the FAST Programme (forecasting and assessment in S&T) stemming from the study ‘Europe +30.’ One of the first attempts to institutionalise an activity looking at the future through the assessment of the likely impacts of technology was the creation of the Office of Technology Assessment (OTA) in the US (operational from 1972 to 1995). Projects mainly have social and political objectives and use methods that provide guidance and fundamentals to analyse alternative situations and choices, such as scenarios. General Electric and Shell started using scenarios to support their strategic decisions. In 1976, Shell looked ahead to 2000 by identifying discontinuities in the industry. After the oil crises (1974) almost half of the firms in the Fortune 1000 list of the largest American companies used foresight techniques in their planning processes. The same trends occurred in Europe [UNIDO, 2005].

In Brazil, the 1970s is considered the ‘embryonic phase’ of foresight [Porto, 2012; Massari, 2013]. Theoretical and methodological studies began to be published in Brazil towards the end of the 1970s. Henrique Rattner released the book ‘Future Studies — Introduction to technological and social anticipation’ [Rattner, 1979]. The first formal group to think long-term (prospectively) on S&T policy was formed in 1979 at Unicamp by Amilcar Herrera. The first official and explicit document on S&T policy was published as part of the Development National Plan (I PND, 1972–1974): the Basic Plan of S&T Development (I PBDCT). The second PBDCT, integrated into the II PND (1974–1979) presumed the



creation of the National System of S&T Development (SNDCT) and the National Programme of Post-Graduation (PNPG). The latter demonstrated for the first time a harmony between a national plan and that of S&T [Salles-Filho, 2003].

In 1974, the CNPq (National Council for Scientific and Technological Development) launched the seeds of future studies in S&T policy with its programme of S&T Studies and Policies. This was reoriented in 1982 to support national and sector S&T policies looking at: i) the assessment of economic, social, political and environmental impacts; ii) trends and perspectives of the production system and S&T associated needs; and iii) future studies methodologies in S&T policy, with particular attention to scenarios.

In the 1980s worldwide exercises began to consider multiple futures embracing global and social uncertainties. In 1983 the term foresight came to be connected to S&T at SPRU in University of Sussex in the UK; in 1985, Michael Godet developed the school 'La Prospective.' Institutional foresight caught the attention of national governments as an activity associated with identifying long-term priorities and developing S&T policies. Activities developed in France (National Colloquium on Research & Technology) and the Netherlands (Ministry of Education and Science) are good examples [Papon, 1988; van Dijk, 1991]. The EU launched FAST Programmes 2 and 3. In Latin America an attempt called 'Prospectiva Tecnológica para América Latina' (1982) tried to identify the main trends of technological change that could become widespread in the next decades and the social, environmental and cultural impacts of technological change in Latin America.

In Brazil, the 1980s was considered to be the 'emergency phase' of foresight [Porto, 2012; Massari, 2013]. In 1985, the first formal course in future studies was delivered to government agencies and bodies, and in 1988 CNPq organised the country's first International Seminar in future studies, evaluation and social participation. Scenarios started being used in the second half of the decade by governmental companies that operate in long-term sectors such as energy [Buarque, 1998]. Examples of this are the BNDES (a development bank) which embedded scenarios in its strategic planning process in 1984; Eletrobrás/Eletronorte (an energy firm) in 1987; and Petrobrás (an oil company) in 1989 to analyse the market and demand for energy and fuel. In fact, Petrobrás initiated the use of scenarios together with BNDES in 1986. In 1987 CENPES (the research branch of Petrobrás) developed its first technological scenarios, and in 1989 scenarios became an intrinsic part of its strategic planning.

Scenarios also had an influence on business and academic environments. The results of the 'scenarios for the Brazilian economy — competitive integration' [BNDES, 1984] proposed an update of the country's industrial structure, suggested measures to achieve an open and competitive economy, highlighted ways to renegotiate Brazil's external debt in the long term. These suggestions were later enacted by the government of President Fernando Collor in the 1990s.

In addition, the creation of the National Council of S&T (CCT) in 1985 influenced the rebirth of futures thinking in Brazil, although its fragile institutional setting (initially subordinated to SEPLAN/PR) and excessive preoccupation with a short-term agenda led to the termination of long-term planning. The ministerial management of S&T in the period known as the New Republic (1985–1990) improved financial and operational aspects but did not fix problems of insufficient coordination.

Foresight exercises in the 1990s were widely undertaken by governments, the national academy of sciences and other governmental departments worldwide, industrial associations, firms, as well as by advisory groups and research advisors. Large-scale programmes took place in Germany, France and the UK, which inspired other EU and OECD countries, as well as Latin American and Asian countries (notably Japan, Korea, China and India) to initiate their own national programmes. Science and Technology were the central foci of these activities that aimed to identify strategic areas of research and emerging technologies that could reap economic (competitiveness) and social (visions, networks, education and culture) benefits. International groups and institutions were created such as the Global Scenarios Group, the Millennium Project and the Joint Research Centre Institute for Prospective and Technological Studies (JRC-IPTS).

In Brazil, the 1990s were considered to be the ‘dissemination phase’ of foresight [Porto, 2012; Massari, 2013]. EMBRAPA (a governmental food research firm) adopted a long-term approach in its strategic planning. The agribusiness and value chains became important concepts for a more systemic understanding embedded in future analysis. The creation of a new CCT (National Council of S&T) established two boards: i) prospective, information and international cooperation; and ii) regional development. The first board enabled an in-depth debate around the future of the National Science and Technology (NST) system leading to yet another rebirth of futures thinking and its embeddedness in the public sector. Themes like future technologies and the role of information as a transformative instrument gained attention. In 1997, a study was proposed emulating the French Key Technologies project and aimed at identifying technological priority topics of S&T in sectors. The objective was to shape the decisions of CCT as well as to involve the Ministry of S&T and the public sector in thinking about the future in order to define future priorities and strategies. In 1998, the project Brasil 2020, which was initiated at SAE was the first governmental experience in undertaking integrated planning for the country in recent years. It aimed to foster a reflection about the kind of country Brazil would like to be and what was needed to transform such a vision into a reality [Sardenberg, 2001]. Workshops and interviews generated input for scenarios, and a broad consultation of social actors tried to grasp societal aspirations. Equity, justice and quality of life were central aspects of society’s hopes and ambitions: all are still valid today.

As the complexity of societies increased globally, from the year 2000 the scope and focus of foresight activities enlarged to cover a number of themes. Foresight exercises changed from emphasising scope and coverage to the process, adapted to a world with greater complexity, interconnectivity and interdependencies. Foresight tried to answer the grand challenges and needs for sustainable public policy in an adaptable way. The understanding of complex systems and possible future behaviours of social actors became the departing point and the focus became challenges instead of decision-making bodies. Coordination of societal actors to solve common problems was sought out, and foresight became institutionalised in Australasia (Australia, Korea, China, Taiwan, Singapore, etc.) beyond the EU and Japan, amongst other countries. UNIDO, in 2000, launched an ambitious programme of Technology Foresight for Latin America and the Caribbean, and UNESCO developed possible scenarios and social policies for Latin America and the Caribbean in the project ‘Rethinking Latin America’ (2011).

In Brazil, the ‘continuous dissemination and generalisation phase’ of Foresight began in the year 2000 [Porto, 2012; Massari, 2013]. The sectoral funds and a movement initiated by the Ministry of Science, Technology and Innovation (STI) led to a revolution in STI at the beginning of the 2000s. However, these have been partially discontinued in recent years. Nevertheless, the seeds that germinated from the CCT resulted in the creation of the ProspeCTar programme (Ministry of STI) and, to a certain degree, the Brazilian Programme of Prospective Industrial Technology (PBPTI) within the Ministry of Development, Industry and Commerce (DIC) in partnership with UNIDO. Delphi methods were the main technique used. The project ‘Tendencies’ of the Ministries of STI and DIC supported by the Sectoral Fund of Oil and Gas aimed to achieve a wide understanding of trends for the sector over the next 10 years. The methodology embraced scenarios, diagnosis, desk research, text mining, expert panels, web Delphi, and other methods. The project’s ‘strategic directives’ (DECTI) resulted, in 2001, in the Second National STI Conference and in the creation of the Centre for Strategic Studies and Management in Science, Technology and Innovation (CGEE) to institutionalise foresight and policy evaluation studies nationally. According to Santos and Fellows-Filho, other results from the Second National STI Conference were the publication of the Green Book (showing the STI trajectory over the last 50 years together with transformative initiatives and future opportunities) and the White Book (showing the STI issues that national STI policy should tackle over the next 10 years to 2012 to consolidate a national STI system) [Santos, Fellows-Filho, 2009]. The project ‘Brazil 3 Times’ (NAE/

PR) aimed to define the strategic long-term objectives for the country and to build a pact between the state and society to achieve these objectives, beyond trying to institutionalise a long-term vision in public strategic management. The project mainly used scenarios. Embraer (an aviation firm) uses scenarios and Delphi routinely and, more recently, simulation systems to detect emerging signals. Technology foresight in Brazil is used as an instrument to formulate STI public policies with a focus on sectors and value chains. However, despite all the above-mentioned activities, the results have not had the expected impacts as they have in other countries. Aulicino observes that possible failures reside in the ways in which these exercises were formulated, designed and executed [Aulicino, 2006]. According to him, all lacked public participation. In addition, Aulicino argues that there was a lack of understanding of the concepts, objectives and expected impacts of these exercises, which led to little engagement and sharing of ideas between social actors, as well as the absence of new networks that were expected as a result.

Table 1 summarizes the stages of Foresight evolution worldwide, and Table 2 — these for Brazil.

Foresight in Brazil is still marked by a dichotomy between discontinuity and the institutionalisation of activities that can become embedded explicitly in decision-making and planning processes. At the same time, the focus needs to shift from technology alone to innovation more broadly to identify and articulate anticipatory intelligence that serves to reorient the NIS systemically, thus embracing social, environmental, economic, political, technological and behavioural (values) aspects. Coordination between decision-making bodies (i.e. Ministries) and social actors (fostering broad societal participation) still needs to be more widely promoted with a focus on challenges or common problems. Moreover, fostering dialogue and participation instead of stakeholders' consultations alone is important for attaining a more systemic understanding of the challenges at hand as well as to build the commitment of individual actors to collective decisions. Finally, promoting these changes means that there is a need to shift the focus of foresight activities from optimisation alone to one that builds a bridge between optimisation and contingency at the same time as embracing uncertainty, complexity and creativity.

## Orienting the National Innovation System through Foresight<sup>1</sup>

In recent years, the ways in which NIS can be reoriented to address grand challenges have been widely debated. According to [Cagnin *et al.*, 2012], these are challenges which are complex and difficult, even impossible, to solve by single agencies or through rational planning approaches alone. Academics and activists have understood this for some time and the articulation of these challenges is not new. The novelty here relies on the increasing attention given to such issues when formulating national STI policies. The reasons for this are complex. In part, it reflects the increasing perception of urgency in responding to a series of challenges that could, if neglected, have devastating consequences of a local or global scale in the next decades. However, it also reflects an attempt to redirect STI efforts, at

Table 1. **Evolution of Foresight worldwide**

Years	Foresight generation	Foresight mode
1950–1960s	1	I
1970s	2	I
1980s	3	I
1990s	4	I
2000s	4, 5	I, II

Source: author.

Table 2. **Stages of Foresight evolution in Brazil**

Years	Foresight generation	Foresight mode
1970s (embryonic phase)	—	—
1980s (emergency phase)	1, 2	I
1990s (dissemination)	2, 3	I
2000s (continuous dissemination and generalization)	1–3	I

Source: author.

<sup>1</sup> Cf. [Cagnin *et al.*, 2012].

least those financed by the public sector, to explicitly respond to political agendas. The central question is how to support such a mission focused on challenges to develop innovation practice [Freeman, 1970; Rogers, 1995; Freeman, Soete, 1997; OECD, Eurostat, 2005; Fagerberg et al., 2004; Hall, Rosenberg, 2010] which is more directed and transformative through the use of foresight methods and approaches [Cagnin et al., 2012].

Foresight processes and approaches offer decision makers the potential of seeing through disruptive transformations, which are necessary as a solution to or caused by grand challenges. From the perspective of transcending epistemological and ontological barriers to better respond to grand challenges, foresight brings long-term perspectives and different knowledge bases into the decision-making process. In doing so, it emphasises the multiple and holistic approaches under which it is possible to identify diverse triggers and instruments to shape the direction of innovation systems. These processes also help in the use and management of the uncertainties associated with the activities and functions of innovation systems [Bach, Matt, 2005; Bergek et al., 2008; Edquist, 2008; Hekkert et al., 2007; Jacobsson, Bergek, 2006; van Lente, 1993; von Hippel, 2005; Woolthius et al., 2005], as well as with the future more widely. It does so through the creation of spaces for social, economic and political actors to meet and appreciate their positions vis-a-vis possible future directions of innovation [Cagnin et al., 2012].

From the political perspective, the potential of coordination improves the communication and the understanding between different decision-making bodies that are giving support, therefore, for the emergence of an effective combination of policies that fosters innovation. Finally, the simple fact of participating in such processes can in itself be transformative by encouraging the adoption of new perspectives and the development of new abilities to detect and process weak signals of change. In this way, different approaches and processes can enable actors to become more adaptive and capable of realising systemic changes. To do so, foresight can assume different roles to orient innovation systems so that the latter are better able to respond to grand challenges [Cagnin et al., 2012]. These roles can be grouped as follows: informing the decision making process, structuring and mobilising networks of actors, and enabling innovation system actors [Barré, Keenan, 2008; Da Costa et al., 2008; Cagnin et al., 2011; Cagnin et al., 2012].

### Foresight at CGEE

The mission of the Centre for Strategic Studies and Management in Science, Technology and Innovation (CGEE) is to promote Science, Technology and Innovation (STI) to advance economic growth, competitiveness and well being in Brazil. It does so by carrying out foresight and strategic evaluation studies in combination with information and knowledge management approaches and systems. At the core of its activities is its position and ability to articulate and coordinate diverse actors within the Brazilian National Innovation System (NIS). One of CGEE's institutional objectives linked to its mission is to lead foresight studies that generate anticipatory intelligence for the Brazilian NIS.

The institution is changing its approach to developing and addressing new strategic questions, and in recognising new issues, which merit further investigation via systemic and systematic observations and dialogue. It is doing so to evolve its foresight practice to combine generations one to five as well as 'modes' 1 and 2 (see introduction), and to enable its results to be better positioned to support a reorientation of the Brazilian NIS.

In this context, CGEE is undertaking a transformative process by changing its approach to designing, organising, implementing, managing and evaluating its foresight studies. The aim is to move from a normative and prescriptive approach to one that embraces complexity, emergence and novelty. The institution is moving in this direction to improve the quality and robustness of its anticipatory intelligence and to increase the preparedness of the NIS for disruptive events [Cagnin et al., 2012]. CGEE is attaining this objective via the creation of spaces for dialogue between key players from different domains, with diverging views and experiences. These spaces are designed to develop vision- and consensus-building



processes for considering and inducing ‘guided’ processes of transformation, as well as to shape and define dialogues on likely transformations and policy discussions on tackling major changes, and on research and innovation agendas. A number of tools and approaches are being explored to enable the institution to advance in such a direction and to use the future to ignite and expand the collective imagination and understanding of the present.

It is important to note that the approach developed by CGEE considers three integrating themes that determine the quality of foresight processes [Cameron *et al.*, 1996]:

- **Expertise** (i.e. ability to understand the nature of the problem/challenge at hand, to recognise the emergence and substantive patterns of change from weak signals in a noisy environment and from collective distributed intelligence);
- **Creativity** (i.e. capable in the art of embracing ‘know knows’, ‘known unknowns’, ‘unknown knowns’ and ‘unknown unknowns’, thus considering knowledge, opinions, speculations and conjectures. In addition, this includes the ability to imagine, to experiment and to interpret novel and transformative possibilities of the future in the present, the ability to embrace the emerging future, and the ability to tell stories through narratives and visualisation);
- **Interaction** between government, science and industry, policy makers and politicians.

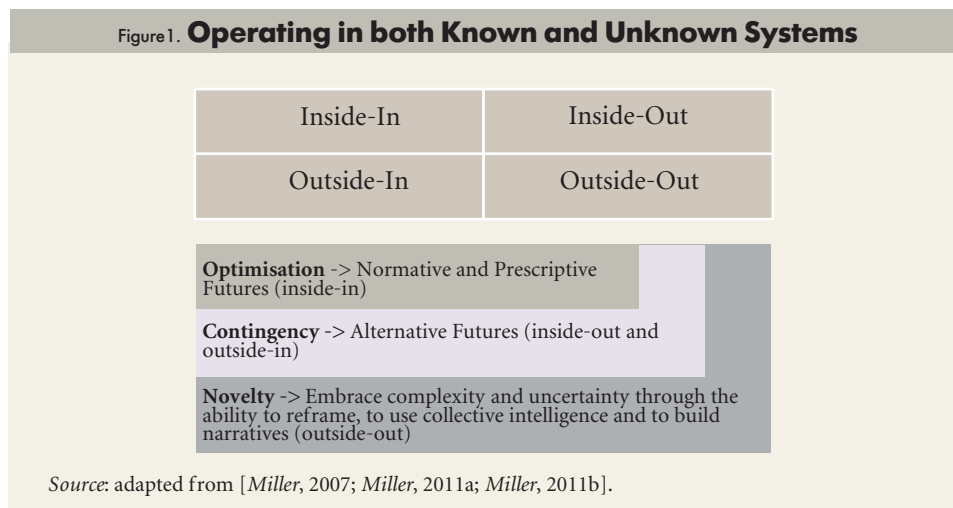
Therefore, the aim of foresight at CGEE is to balance contextualised design with systemic and systematic qualitative and quantitative approaches, and to welcome unknowability and uncertainty as a source of novelty, thus also providing an invitation for creativity and improvisation. Working with possible, probable, desirable, plausible and reframed futures provides a way to work with unknowable futures and novel frames for imagining the future [Miller, 2011a; Miller, 2011b]. Foresight does so by exposing anticipatory assumptions and revealing the social processes and systems used to invent and describe imaginary futures [Miller, 2007; Miller, 2011a; Miller, 2011b]. The author affirms that such processes increase our capacity to imagine discontinuity and to put more effort into inventing what is unknowable, thus developing greater capacity to use the future; what he calls ‘futures literacy’.

Developing the above mentioned balance implies building an ability to ‘walk on two legs’<sup>2</sup>: to improve or optimise the current system simultaneously as it moves towards new and/or disruptive system configurations. Being able to operate in both known systems (inside-in, inside-out, and outside-in) with more efficiency and efficacy and operate in unknown systems (outside-out), according to Figure 1, will help the institution craft strategic questions for itself and its clients. In other words, looking outside the system with which we are familiar will help us develop and address new strategic questions, but also assist us in recognising new issues (e.g. challenges, technologies, social transformations, etc.) through systematic observations and dialogue, and in selecting those which are worth further investigating to identify new opportunities.

In short, optimisation focuses on the improvement of existing systems and looks at the future detached from the present. It usually allows for incremental innovation based upon a normative future with prescriptive actions associated. It prepares one to operate in known systems or ‘inside-in’ which, in other words, means that the boundaries of the system are well understood and only what resides within such boundaries are analysed.

Contingency, on the other hand, focuses on avoiding the undesirable events or on preparing the current system to continue to exist in the future. It also looks at the future detached from the present, and importantly looks at alternative futures instead of looking at one single vision alone. The aim is to enable one to prepare for different possibilities of the future regardless of whether these become a reality or not, as well as to shape a desirable pathway with checkpoints that —

<sup>2</sup> Presentation delivered by Riel Miller in the Futures Literacy UNESCO Knowledge Labs (FL Uknowlab) or Local Scoping Exercises (LSE), held by UNESCO in 2013 in a range of countries, e.g. Germany, Norway, Brazil, Columbia, etc. See, e.g. [Miller *et al.*, 2013].

Figure 1. **Operating in both Known and Unknown Systems**

when monitored — enables one to adapt to new events or situations along the way. Here beyond looking ‘inside-in’ (within known systems) it enables one to look both ‘inside-out’ and ‘outside-in’ the system under analysis. In other words, it enables one to identify how changes in the system being analysed (therefore known, at least partially) can impact other systems and vice versa. Innovation promoted here is also incremental but with the potential to foster more radical or disruptive innovation.

Being able to embrace complexity and uncertainty, however, means putting a stronger focus on narratives and the ability to reframe (questions, concepts, cultures, etc.) our images and metaphors about the future. According to Miller, this means that the future is not detached from the present but is an alternative intrinsic part of it, which enables us to embrace the ‘unknown’ and the unexpected in the present while the future unfolds [Miller, 2011a; Miller, 2011b]. The focus is on more than one transformative future (‘outside-out’) that is open to discontinuity as well as to birth and rebirth. In the end, such an approach allows for both incremental and radical or disruptive innovation, with experimentation being at the heart of our capacity to cultivate and reap the new and the unexpected [Miller, 2011a; Miller, 2011b].

Based on the above, the direction in which foresight is evolving at CGEE aims to enable the institution to operate at of all the above-mentioned systems in parallel. In doing so, it invites uncertainty, complexity and creativity throughout the process and translates these into actual recommendations for policy design and implementation or into new strategic questions that should be investigated and addressed to reorient the Brazilian NIS. F

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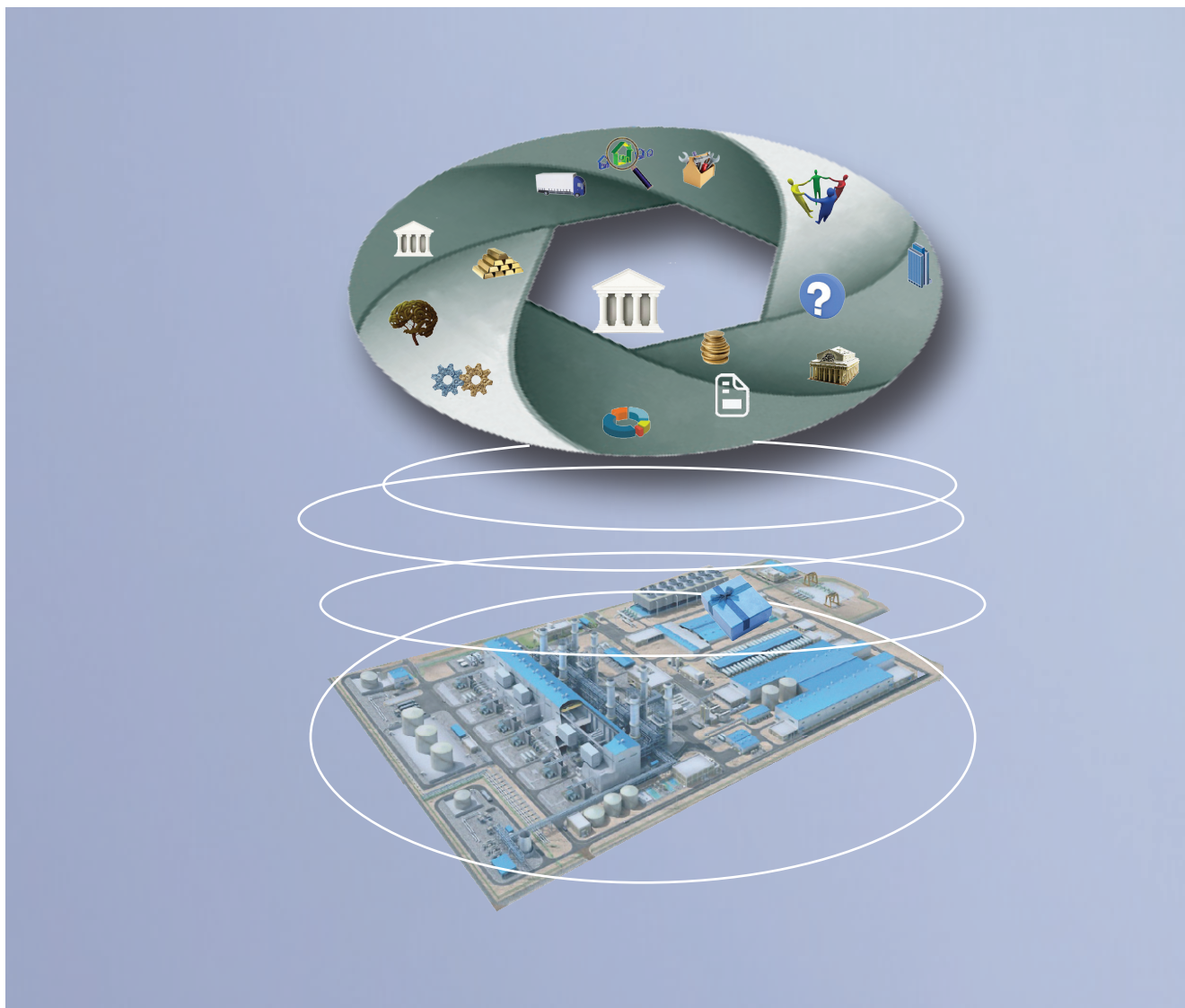
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# Modern Notation of Business Models: A Visual Trend

Tatiana Gavrilova, Artem Alsufyev, Anna-Sophia Yanson



Information overflow and dynamic market changes encourage managers to search for a relevant and eloquent model to describe their business. This paper provides a new framework for visualizing business models, guided by well-shaped visualization based on a mind mapping technique.

Due to the simplicity of perception, this approach has a positive impact on managers and employees' understanding of companies' business models and promotes a productive exchange of ideas and knowledge. The mind-mapping visualization framework is 'cognitive scaffolding' and is positively associated with managers' and employees' improved perception and understanding of the business model, which allows them to communicate, share and manipulate business model knowledge easily.

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## Keywords

business model; mind mapping; visualization; Canvas business model; innovation activity

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In recent years the concept of a business model has become widespread. In essence, every company follows some sort of business model which has come about either spontaneously or as a result of deliberate efforts. The concept's popularity is connected to the development of innovations. By 'innovation' we mean an activity that extends beyond an organization, which, as has been noted by several authors, requires the development of new, relevant, and flexible tools for management and business modeling [Zaytseva, Shuvalova, 2011] in the context of 'models of open innovation' [Chesbrough, 2003]. The new challenges presented to companies by a rapidly growing environment impel them to adapt their own strategies to deal with expanding global competition, which is becoming increasingly knowledge-based [Guinet, Meissner, 2012].

New technologies require novel business models that allow companies to convert technological innovations into commercial successes. The business models themselves undergo constant changes, so the main task of entrepreneurs and managers is to adjust the overall direction of their company's development and, in particular, their chosen model [Voelpel et al, 2005]. In this sense, business models become constantly and spontaneously evolving systems, with their own structure and internal behaviour [Mason, Spring, 2011].

In particular, the success or failure of a corporate strategy frequently depends on the business model, which forces companies looking for sources of growth to make innovative changes to their processes and products. This in turn determines the interest in researching ways to create new business models and adapt existing models to a dynamic market environment. A 'business model' is a relatively new concept of modern business and strategic management, so it has many unsolved questions and problematic areas. Its study is also relevant due to the lack of a unified approach to understanding business models and the undeveloped conceptual and methodological foundations for creating and analyzing business models. Despite broad academic discussions, today there are still very few systematic investigations of these problems. The question of the extent to which various business models are distributed throughout the economy and their relative financial efficiency has not been adequately studied.

Most of the existing scientific research has addressed the business models of information- and communications technologies (ICT) companies. A survey of professionals confirms the lack of a common opinion as to the definition of the term 'business model.' Nevertheless, it is possible to identify the primary areas of research in this field. In particular, business models are regarded as new analytical units, which are used to describe how companies operate their business, and finally are about *how value is created* rather than only how this value is preserved and multiplied.

Thus, a business model acts as an important point for the application of organizations' efforts [Chesbrough, 2006; Christensen, Raynor, 2000]. Of special interest is the development of new business models, which is dictated by changes in the market or an internal crisis within a company in general or a current business model in particular [Johnson et al, 2008; Meehan, Baschera, 2002].

Most research in this area has been focused on companies' interaction with their network of partners, since corporate management using business models is by no means performed in a competitive vacuum [Hamel, 2000]. Experts have noted that the business models themselves are a point of competition between players [Casadesus-Masanell, Ricart, 2010]. In other words, they are a potential source of advantages in the market [Markides, Charitou, 2004]. In recent years the emphasis of research has shifted to studying innovative business models that companies have used to essentially commercialize breakthrough ideas and technologies.

Moreover, the business model itself frequently becomes the object of innovative activity, complementing traditional forms of cooperation and interaction and proposing new forms of collaboration.

In today's economy, a company's success depends on developing new products, introducing new processes in production and management, and marketing innovations [Prazdnichnykh, 2013]. By analyzing the results of IBM's 'Enterprise of the Future' global research, Kirill Kornilev underscores the fact that a successfully functioning firm in the future must not only constantly change but also offer the market innovations that surpass customers' and partners' needs [Kornilev, 2009]. In management that imperative finds expression in the various ways in which business processes are organized, for example, in business groups [Avdasheva, 2005], online collaboration between companies [Rumyantseva, Tretyak, 2006], and integrated business models [Zinin, 2008]. The creation of an entrepreneurial orientation in Russian companies (i.e. the creation of organizational characteristics aimed at finding new market opportunities) is also a motivation to change the logic of business operations [Shirokova, Sokolova, 2013; Shirokova, 2007].

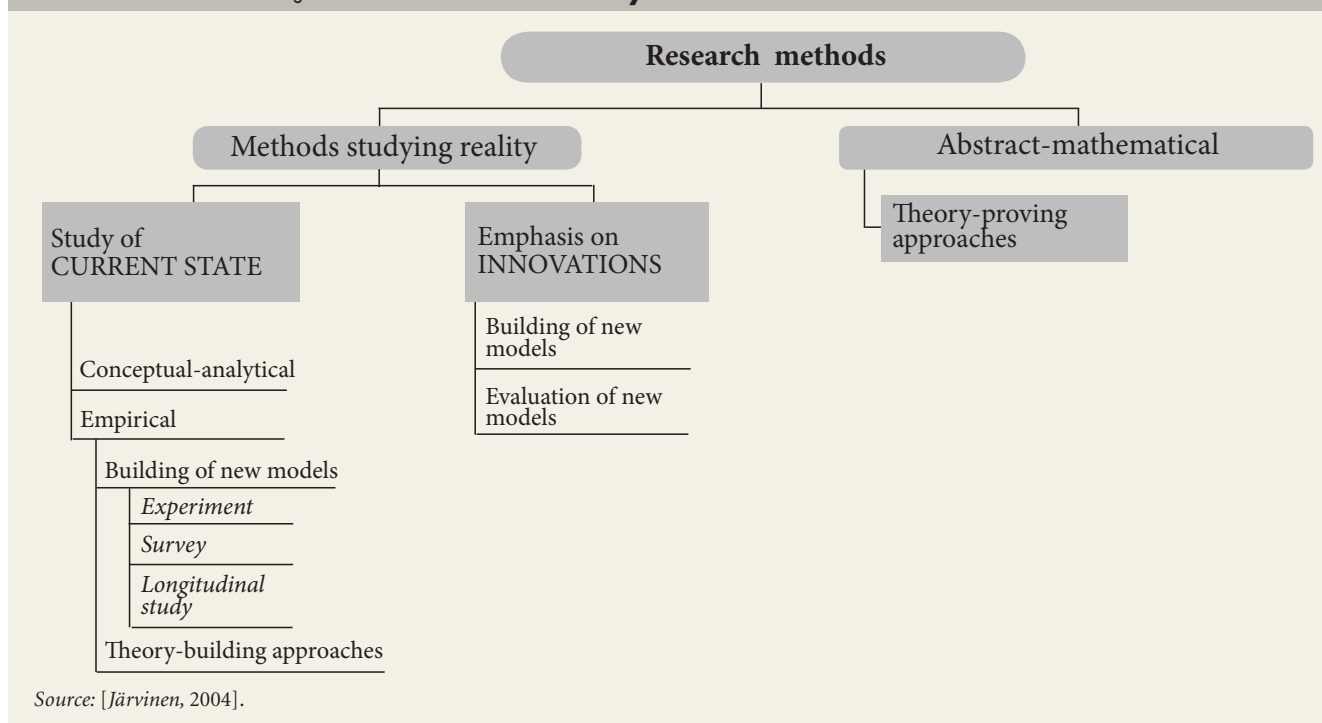
This paper presents the results of research that compared various ways of describing and presenting business models. In the presentation of business models, we have emphasized the graphical presentation of information because researchers' general opinion is that visualization facilitates the comprehension of business processes [Card et al, 1999; Eppler, 2006]. For example, one of the world's most influential experts in information design, Edward Tufte of Yale University, asserts the effectiveness of visualization when working with both qualitative and quantitative data [Tufte, 2006].

We again underscore the fact that the development of a business model is a complex corporate task requiring the participation of several top managers and business analysts. Ideas are generated in groups interacting formally and informally [Garfield et al, 2001; MacCrimmon, Wagner, 1994], which gives the work social and cognitive dimensions [Dennis et al, 1999; Garfield et al, 2001; Nagasundaram, Dennis, 1993]. The formation of these groups, which are a source of dynamic changes, is an important initial stage of work [Chanko, 2008]. The productive development of a business model requires the creation of new knowledge, and the exchange and integration thereof [Gavetti, Levinthal, 2000]. Thus, one of the fundamental tasks in initially designing a company's business model is to improve the effectiveness of group interaction, develop the creative potential of employees, and overcome certain social and cognitive problems. Using the terminology of Bentsion Milner, knowledge must be identified, extracted, and formalized to create a social and scientific strategy of training and innovation [Milner, 2004].

As mentioned above, the effectiveness with which a business model is comprehended grows substantially if it, or parts thereof, is presented graphically. This explains in particular the success and wide circulation of a new and innovative tool known as the business model canvas, which was developed by Alexander Osterwalder and Yves Pigneur [Osterwalder, Pigneur, 2010]. The template has been recognized by both business model theorists and practitioners [Chesbrough, 2010]. However, despite the numerous examples of successful application, its effectiveness remains unclear and hence needs to be analyzed in depth.

In this paper, we attempt to extend the business model canvas [Osterwalder et al, 2005] to achieve the most compact, most information dense, and most abstract template. The proposed approach to visualization of business models uses modern theories of knowledge engineering, cognitive sciences, and Gestalt psychology [Adeli, 1994; Solso, 2001; Gavrilova, 2002]. In developing our approach, we employed techniques for building hypergraphs, particularly *mind maps* [Buzan, 2003].

Figure 1. Järvinen's taxonomy of scientific research methods



The question we sought to answer was: ‘Does a new visual template of a business model in the form of a mind map help more fully reflect the ideas and logic of a company’s business processes?’ In other words, we explored the potential of visual modeling for the purpose of facilitating comprehension of business models in comparison with traditional textual and tabular formats.

## Research Methodology

Management theory is one of the youngest fields of knowledge. From the start, its main source was applied management practice, i.e. chiefly empirical knowledge. Even today specific management experience remains an important source of learning and growth for management theory.

Thus, the traditional approach to scientific research in this field is underpinned by empirical models, usually based on the results of statistical analysis of data samples [King *et al*, 1994; Lysov, 2006; Mangeym, Rich, 1999; Shchedrovitsky, 1981]. The data come from surveys, observation, questionnaires, focus groups, and other methods of gathering primary information [King *et al*, 1994; Lysov, 2006; Mangeym, Rich, 1999; Shchedrovitsky, 1981]. Secondary information is also useful. Here, the research started from a set of several hypotheses, which were then subsequently proven or refuted.

Other methods of research also exist. Fig. 1 illustrates the approach of the Finnish methodological school under the leadership of Pertti Järvinen [Järvinen, 2004, 2008], who proposed a taxonomy of scientific research methods based on the ideas of a number of western scientists [Gregor, Jones, 2007; March, Smith, 1995; Yin, 1989].

As Fig. 1 shows, our approach is part of a group of innovative methods that attempt to understand reality by building new conceptual models and evaluating them based on specific criteria. Such an approach facilitates the quick development of an organization’s business model with the help of a mind map template (see below). The results obtained have confirmed our hypothesis that the concept of business model visualization we have developed using a mind map may be a real innovative tool for optimizing business communications. Such a form of presentation has a positive im-

pact on managers' and employees' comprehension and understanding of the business model. It promotes effective interaction between them, the exchange of ideas, and the use of knowledge embedded in the business model.

### State of modern research on business models

The term 'business model' originated in the field of data and process modeling [Osterwalder *et al*, 2005], entrenching itself among researchers and practitioners of new technologies in the late 1990s. Later the concept began to be used in management and educational circles. Authors of the definitions in the literature note that a company's business model, in essence, explains how the firm creates value and how the different parts of a company interact with one another [Magretta, 2002].

The prevalence of the word 'business model' came about largely through economic globalization and the development of online business [Bellman *et al*, 1957; Osterwalder *et al*, 2005]. The term's multiplicity of meanings is explained by the fact that at various stages the concept of 'business model' included many different economic factors, such as ways to create shareholder value, elements of industry regulation, new forms of income and income models, as well as complex intercompany relations [Redis, 2007].

Most researchers understand a business model to be one of the following:

- 1) a tool for representing the value created by a company [Shafer *et al*, 2005];
- 2) a systematic description of the mechanism of interaction with partner businesses [Amit, Zott, 2001];
- 3) a cognitive tool for converting technological developments into economic returns [Chesbrough, Rosenbloom, 2002];

Osterwalder and Pigneur conducted a detailed analysis of the literature dedicated to business models and propose the following definition:










'A business model is a conceptual tool that includes a set of parts and their interconnections, and that enables the representation of how a company makes money' [Osterwalder, Pigneur, 2010].

Osterwalder and Pigneur's full definition includes important parameters such as 'partner network.' A business model describes the logic of a value-creating system, which forms the basis for actual corporate processes. Formation of and compliance with a company's business model is one form of knowledge management [Mustafa, Werthner, 2008; Hajiheydari *et al*, 2012; Rajala, Westerlund, 2005; Lopes, Martins, 2006], a field that has recently attracted the attention of business researchers and practitioners. An important characteristic of companies turning to knowledge management is *knowledge intensity*, a property that is rather ambiguous and difficult to observe and operationalize [Doroshenko, 2007; Doroshenko, 2011]. An important step in the optimization of the knowledge management process is to clearly create the model itself. In the field of knowledge management, this process is known as externalization or the conversion of tacit knowledge into explicit knowledge [Nonaka *et al.*, 1995]. It is also important that most of a business model's parameters can be visualized, compactly described, and lend themselves to various manipulations and adjustments.

Various approaches to defining 'business model' have been often proposed [Sabir *et al*, 2012]. A natural consequence of such diversity is a multiplicity of approaches to the visualization of business models [Chang *et al*, 2010; Osterwalder *et al*, 2005; Osterwalder, Pigneur, 2010; Osterwalder, 2004; Sabir *et al*, 2012; Samavi *et al*, 2008; Scütz *et al*, 2013]. However, the primary form of presenting corporate knowledge is still the familiar linear text in natural language. The main advantage of text is its well-established,



Table 1. **Canvas business model for KFC**

<b>Key partners</b> Pepsi, food suppliers 	<b>Key activities</b> Management of a chain of fast food restaurants, logistics system, franchising, catering services  <b>Key resources</b> Brand, sales and logistics network, facilities to support the catering service 	<b>Value propositions</b> Secret recipe, affordable prices, fast service 	<b>Customer relationships</b> Focus on customers' needs: individual and standard contracts  <b>Channels</b> Fast food restaurant chain, home service, online stores 	<b>Customer segments</b> Young people (16-25 years old), students, Early career workers, franchisees 
<b>Cost structure</b> Costs of the fast food restaurant chain, branding/communications, fleet of catering vehicles, food innovations 	<b>Revenue streams</b> Revenue from the fast food restaurants and catering service, franchising 			

Source: prepared by the authors.

predictable, and simple format. However, understanding text is associated with activity in the left (logical) hemisphere of the brain and does not use the cognitive resources of the right (creative) hemisphere, which means it is not sufficiently effective.

As we mentioned above, one of the most popular practical tools for visualization and development of business models is the business model canvas. An example of one is shown in Table 1, which is a variation of a business model developed for the company KFC.

The business model canvas traditionally consists of nine blocks that reflect the structure of business processes. First, with the help of *key partners* and *key resources*, a company performs certain types of activities. These *key activities* meet customers' needs by creating a *value proposition* that is sold through *sales channels*. In each *customer segment*, *customer relationships* are established. Using a value proposition that has been successfully delivered to the customer, a company generates *revenue streams*, which must exceed the organization's *costs* to perform these activities.

A 'canvas model' is essentially a blank table that can be completed. To improve comprehension, visual elements are added to the table, whose relevance and effectiveness require separate research.

## Mind maps as a tool for developing a business model

The primary cognitive benefit of visualization is the simplicity of extracting and synthesizing information. Any form of graphical representation is effective thanks to:

- 1) the message's high capacity and ability to be understood by users;
- 2) minimal effort required to find information;
- 3) the ease of conveying certain inferences;
- 4) an attention switch mechanism;
- 5) the encoding of information [Schneiderman, 1996].

Visualization's social benefits include the ability to integrate different points of view, which promotes mutual understanding and facilitates interaction between people in a team. The emotional benefits are in turn associated with feeling involved in the team's work and — controversially for some authors — the development of creative potential and the strengthening of relations between employees.

Regarding the cognitive advantages of different types of information, many researchers have noted a substantial increase in the effectiveness of comprehension when using a visual form of communication [Larkin, Simon, 1987; Tversky, 2005]. According to Iris Vessey, visualization helps solve complex tasks by compressing information [Vessey, 1991]. When processing large amounts of information, visualizing the data makes it more easily analyzed and makes patterns more easily identifiable [Card et al, 1999; Tufte, 1991]. Empirical studies have confirmed the advantage of visual solutions over verbal (textual) solutions in a wide spectrum of applications [Bauer, Johnson-Laird, 1993; Glenberg, Langston, 1992; Larkin, Simon, 1987]. Visualization frees up additional working memory in humans [Norman, 1993], thereby simplifying memorization and retention of details [Lurie, Mason, 2007].

Visualization helps information to be assimilated well through the use of graphical metaphors [Morgan, 1986]. By simplifying extraction and synthesis, it makes it possible to process larger volumes of data without the risk of overload. Graphical presentation of data induces hidden mental schemas used in decision making and fosters the integration of the views and ideas of a team of employees. In the process of developing a business strategy, visualization is used when generating various scenarios and possible actions. These actions may include potential strategic objectives, stages of implementation, and a forecast of the flow of the company's resources.

Well-executed modern visualization uses a broad set of computer graphics tools that are favourably understood by managers and analysts and have a motivating effect on employees [Babkin et al., 2011]. Available software makes it possible to solve complex technical tasks and effectively coordinate the actions of many participants with relatively modest efforts and few resources [Zaytseva, Shuvalova, 2011; Ivanov et al, 2012]. ICT include organizational innovations in the interaction between economic entities, expanding the opportunities for information exchange [Abdrakhmanova, Kovaleva, 2009].

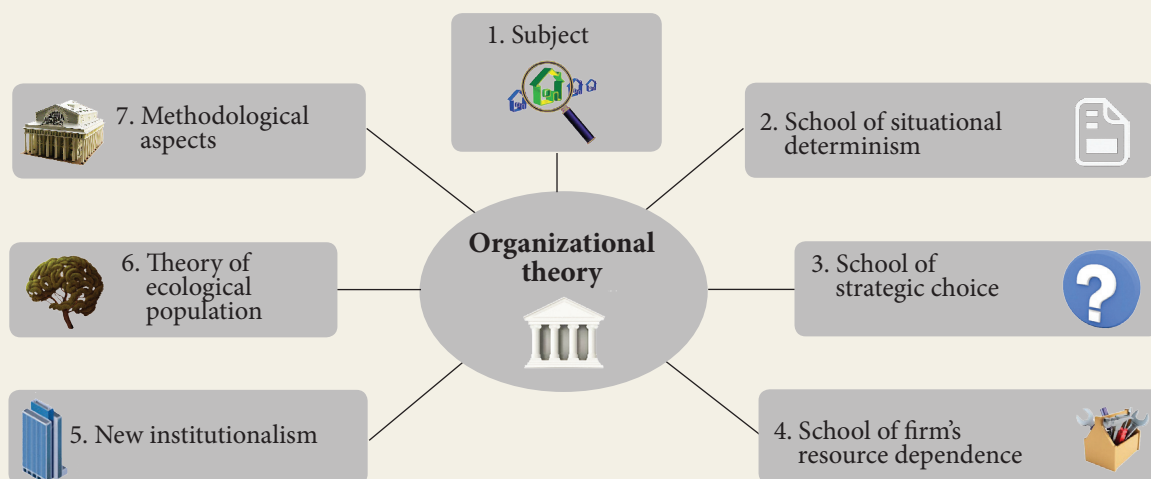
The noted merits of visually presenting business processes are also typical of mind maps as a simple and convenient visual tool for developing business models. Tony Buzan first proposed the term 'mind map' to designate round hierarchical diagrams [Buzan, 2003]. The heart of his idea was to visualize (illustrate) thoughts, concepts, relationships, and associations, by tying them to a central node — a graphical element that reflects the mind map's main idea. An example is shown in Fig. 2. Mind maps are remarkably popular today as a means of processing enormous volumes of business information in large companies [Eppler, 2006; Mento et al, 1999]. Leading global corporations use mind maps in both strategic and operational management. Mind maps differ from other similar tools in that not only do they simplify the structure of connections between elements, they also present a clear, visually-spacious model of the central concept, acting as a kind of cognitive framework for complex and massive concepts. Managers and professionals include mind maps in their presentations because a clear and vivid solution created using one of the many specialized software editors (MindJet, MapIt, Imind, Freeplane, Comapping, etc.) helps hold the audience's attention throughout the entire presentation.

A mind map is effectively comprehensible due to its three main elements:

- the use of colour to separate parts;
- the use of different-sized fonts for elements at different levels;
- the integration of images in order to attract attention.

More and more often companies use mind maps now to develop their employees' ability to think creatively and motivate them to systematize and structure the results of their work. Mind maps are most frequently used in corporate training systems [Gavrilova et al, 2011], brainstorming, presen-

Figure 2. Example of a mind map about organizational theory



Source: prepared by the authors.

tations [Zhelyazny, 2009], and at strategic briefings and meetings [Müller, 2009].

Mind maps make it possible to explain the substance of ambiguous concepts, such as a business model. In particular, a mind map is an effective tool for describing a specific business and presenting its basic and particular characteristics. It is also a means of placing the company's activities into a market context.

## Research methods and main results

Does a mind map template improve managers' understanding of a company's business and logic? The latest research indicates that business model templates, such as the business model canvas previously mentioned [Osterwalder *et al*, 2005], significantly improve the overall comprehension of a company's business processes. However they decrease managers' creative potential and efforts to develop a business model. At the same time, the use of freehand drawings, sketches, pictures, and outlines has a noticeable positive effect on creative potential and the depth of work on a business model [Eppler *et al*, 2011].

Our results allow us to assume that the mind map template we have developed (Fig. 3), which includes elements of the business model canvas, makes it easier to understand the logic and specific characteristics of a business. We have included all nine elements of the business model canvas and combined them into four large groups (meta-concepts):

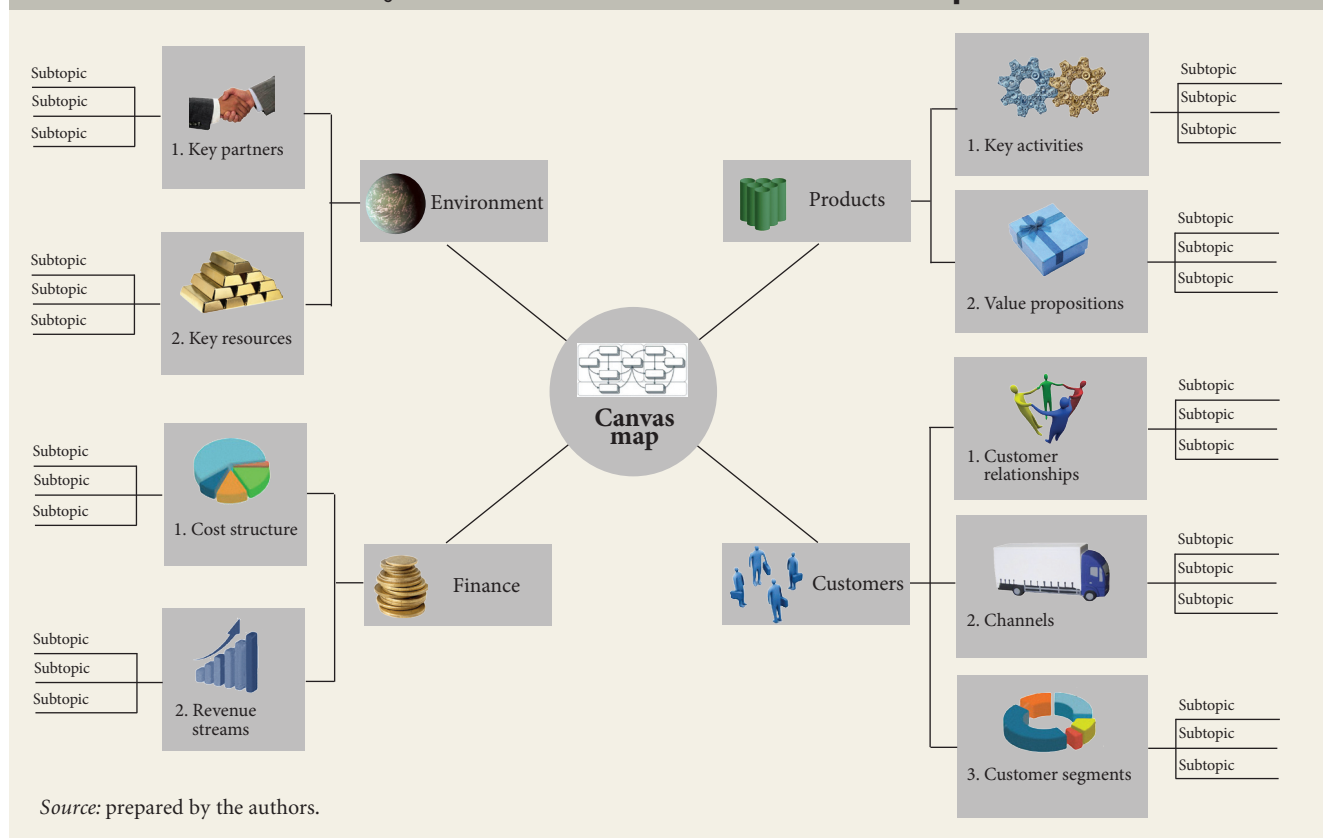
- products;
- environment;
- finances;
- customers.

Like the business model canvas, our mind map template (or canvas map) may be expanded and adapted to the needs of business leaders or groups in developing business ideas for individual or team work.

We propose a modified and simplified four-step algorithm to create such maps for companies' needs [Gavrilova, 2010], which includes the following stages:

- 1) definition of the business model's objectives;
- 2) creation of a glossary or identification of meta-concepts;

Figure 3. Business model canvas as a mind map



- 3) creation of a hierarchy of concepts;
- 4) revision as needed.

We followed this algorithm when creating a canvas map. Objectives were defined in the first stage. We used the business model canvas [Osterwalder et al, 2005] as the foundation for subsequent modifications.

In the second stage we identified four meta-concepts (the clusters of ‘products’, ‘customers’, ‘finances’, and ‘environment’) and allocated the nine blocks of the canvas map to them as follows. The ‘products’ cluster includes ‘key activities’ and ‘value propositions’. The ‘customers’ cluster consists of ‘customer relationships’, ‘channels’, and ‘customer segments.’ The ‘finances’ cluster incorporates ‘cost structure’ and ‘revenue streams.’ The ‘environment’ cluster includes the ‘key partners’ and ‘key resources’ blocks.

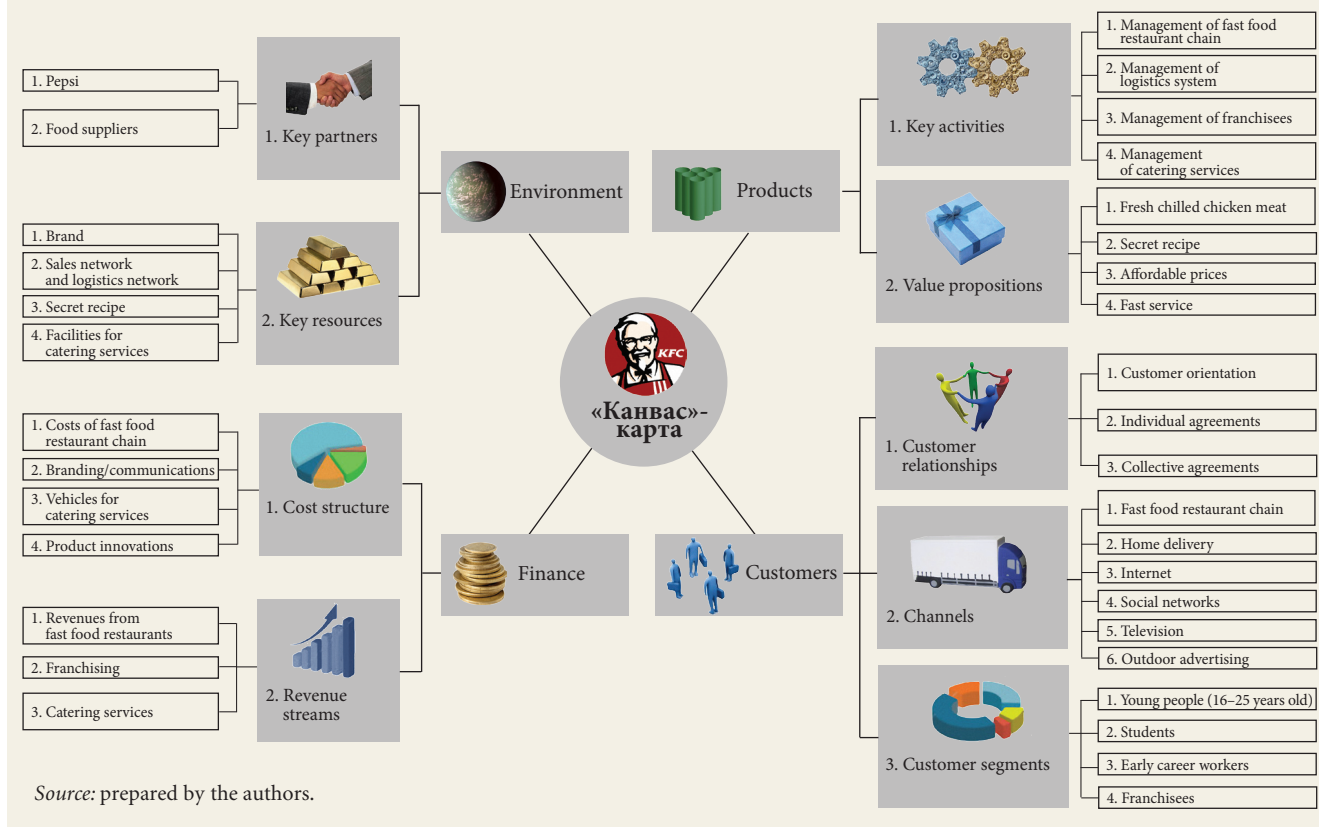
The third stage entails these separate blocks being sequentially filled out based on the conditions, interests, and objectives of a specific company (KFC in our example).

The final stage of developing a mind map of a business model consists of enhancing the diagram graphically by removing redundancies, tautologies, and contradictions. The main purpose of the last stage is to achieve a streamlined and harmonious design [Gavrilova, 2010]. To accomplish this, each branch of the business model map is assigned an individual colour and an illustrative icon is placed in each separate block. In our research, respondents were asked to select the most relevant of five icons that had been associated with each business model’s blocks. The selected icons were subsequently used.

To evaluate the comprehension of the mind map template we conducted a study with 22 top managers (financial directors, heads of marketing and sales departments, deputy directors, and employees) at Russian companies that participated in the Executive MBA program run



Figure 4. Canvas map for KFC



by Saint Petersburg State University’s Higher School of Management in 2011–2013. The objective of the study was to assess the managers’ comprehension of three methods of representing KFC’s business model. The first method included a textual description, the most widespread and traditional form of presenting ideas. The second method was the business model canvas presented in Table 1. The third method of representing a business model involved a template of a business model canvas in the form of a mind map, or ‘canvas map’ (Fig. 4).

During the experiment participants were divided into three subgroups (Table 2).

Each subgroup was presented with one of the three representations of KFC’s business model: textual, business model canvas, and canvas map. The groups were given 10 minutes to familiarize themselves with the business model. Then the participants individually had to answer in written form a series of questions about the company’s business model:

1. What does the company do?
2. Who are the main customers?
3. What are the characteristics of the main customers?
4. What are the main advantages of the company’s products?
5. Where does the company’s revenue come from?

The examples of questionnaires with participants’ responses to the questions (Table 3 below) confirm that all three ways of representing a cor-

Table 2. Makeup of test groups

No.	Group name	Artefact	Number of respondents
1	Group A	Text	6
2	Group B	Business model canvas	8
3	Group C	Mind map	8

Source: prepared by the authors.

porate business model, namely, text, a canvas, and a mind map, contain sufficient information about the company’s activities. The greater degree to which participants in Group C filled out their questionnaires compared to the other two groups allows us to conclude that the business model represented as a mind map is more informative and possibly more understandable.

The respondents' answers were analyzed by four experts in the area of business modeling, who are researchers at Saint Petersburg University's Higher School of Management. They were asked to assess how well the test subjects' answers corresponded to the information about KFC on a scale from 1 to 5, where 5 means ‘fully corresponds to the information presented about the object’ and 1 means ‘in no way corresponds to the information presented about the object.’ Next, three samples of the experts' assessments were generated for each of the subgroups of test subjects.

To compare the three methods of representing a business model, single-factor analysis of variance was performed with a p-value of 0.05 for the three samples (Table 4). The differences in the assessments of the participant groups turned out to be significant for all the questions. We may assert that as a way of representing a business model, a mind map is more effective than a business model canvas or textual representation in terms of information comprehension.

The research was accompanied by a discussion that showed that participants had identified the mind map as the most structured and understandable representation of a business model. Respondents noted that the textual description of a business model is monotonous and uniform (‘boring to read’). They rated the classic business model canvas favourably, although it contains many elements that are often superfluous. Quite a lot of cognitive effort was also required to understand the logic behind the arrangement of the basic elements in the table. Some participants viewed them as unrelated to one another. The use of mind maps made it possible to overcome many of the difficulties that have been described.

### Conclusion

Today’s interest in visualization is not just another fad but rather the result of cognitive overload caused by the immense density of the information field surrounding humans. The results of the majority of interdisciplinary studies in the field of management point to this conclusion. Visualization enables information to be compressed and simplifies com-

Table 3. **Examples of participants’ responses to questionnaires categorized by the three groups**

	Group A (text)	Group B (business model canvas)	Group C (mind map)
What does the company do?	<ul style="list-style-type: none"> <li>• Fast food</li> <li>• Franchising</li> <li>• Catering</li> </ul>	<ul style="list-style-type: none"> <li>• Delivers food</li> <li>• Offers franchises</li> <li>• Logistics</li> </ul>	<ul style="list-style-type: none"> <li>• Fast food restaurants</li> <li>• Catering</li> <li>• Franchising</li> </ul>
Who are the main customers?	<ul style="list-style-type: none"> <li>• Young people up to 25 years old</li> </ul>	<ul style="list-style-type: none"> <li>• Young people - students</li> <li>• People starting their careers</li> <li>• Franchisees</li> </ul>	<ul style="list-style-type: none"> <li>• Young people</li> <li>• Students</li> </ul>
What are the characteristics of the main customers?	<ul style="list-style-type: none"> <li>• They are starting their careers</li> <li>• They sit at home</li> <li>• They love chicken</li> </ul>	<ul style="list-style-type: none"> <li>• Youth</li> </ul>	<ul style="list-style-type: none"> <li>• Young people with low incomes</li> </ul>
What are the main advantages of the company’s products?	<ul style="list-style-type: none"> <li>• 42% of the market</li> <li>• Know-how</li> </ul>	<ul style="list-style-type: none"> <li>• Low price</li> </ul>	<ul style="list-style-type: none"> <li>• Fresh chilled chicken meat</li> <li>• Secret recipe</li> <li>• Logistics</li> <li>• Warehouses</li> <li>• Vehicles for catering</li> <li>• Focus on customers</li> </ul>
Where does the company’s revenue come from?	<ul style="list-style-type: none"> <li>• Warehouses</li> <li>• Logistics</li> </ul>	<ul style="list-style-type: none"> <li>• Catering service</li> <li>• Fast food restaurants</li> <li>• Franchising</li> </ul>	<ul style="list-style-type: none"> <li>• Fast food restaurants</li> <li>• Catering</li> <li>• Franchising</li> </ul>

Source: prepared by the authors.

Table 4. Results of single-factor analysis of variance

		Sum of squares	Degrees of freedom	Mean square	F	Significance
What does the company do?	Intergroup	8.218	2	4.109	5.318	<b>0.015</b>
	Intragroup	14.680	19	0.773		
	Total	22.898	21			
Who are the main customers?	Intergroup	12.632	2	6.316	8.583	<b>0.002</b>
	Intragroup	13.982	19	0.736		
	Total	26.614	21			
What are the characteristics of the main customers?	Intergroup	5.076	2	2.538	4.578	<b>0.024</b>
	Intragroup	10.534	19	0.554		
	Total	15.610	21			
What are the main advantages of the company's products?	Intergroup	6.305	2	3.153	4.209	<b>0.031</b>
	Intragroup	14.232	19	0.749		
	Total	20.537	21			
Where does the company's revenue come from?	Intergroup	5.752	2	2.876	3.586	<b>0.048</b>
	Intragroup	15.240	19	0.802		
	Total	20.991	21			

Source: prepared by the authors.

prehension, which reduces cognitive stress and facilitates more effective mental activity.

A significant number of studies in information design and data visualization are dedicated to the role of graphical methods in management [Eppler, Burkhard, 2007; Eppler, Platts, 2009; Eppler, 2004]. Experts have given special attention to strategic planning and the difficulties that can be overcome by visually representing information [Eppler, Platts, 2009]. They have noted three groups of advantages of the visual approach: cognitive (clarity, order, ease of comprehension), social (ease of communication), and emotional (interest, motivation to work). Visualization reveals the vast opportunities to generalize and systematize data, which promotes effective management of corporate knowledge.

The results of our research demonstrate that using a new visual representation of a business model gets a positive reaction among management practices. Most participants in our study noticed a significant improvement in recall. The testing has established that the visualization tool with a mind map may be considered a graphical template for a cognitive framework that positively affects the comprehension and understanding of a business model.


The structure of the information and the qualifications of the specialists who create the visualization are subject to specific requirements. For example, business information must be sufficiently specific and the specialists must have experience creating mind maps. Due to the study's experimental nature, the proposed method has a number of unavoidable limitations. We found that some people understood the traditional textual format better. This question requires special research into visual representations of business knowledge.

Despite our positive results showing that a business model in the form of a mind map is better understood by managers than a business model canvas and a textual representation, a comprehensive study that includes more factors would be beneficial. First, when analyzing comprehension we propose accounting for respondents' cognitive traits, their motivations, and their experience in working with mind maps. Second, to get more reliable test results it would be necessary to increase the number of respondents and the sample size. Third, we believe that in addition to assessing the comprehension of the visual data in mind maps, it would be relevant to also measure the level of creativity exhibited by managers in

the process of developing a business model. The expert analysis aimed at the determining the creativity of the models produced may be used to measure the visual component's contribution to the effectiveness of teamwork on a business model. Finally, the use of experts' objective assessments of the comprehension of information may not reflect the cognitive characteristics of working with information visually. In other words, using respondents' subjective opinions together with experts' objective assessments may collectively provide a deeper understanding of how effectively managers comprehend visual representations of a business model.

Other necessary issues that further research should address include a careful interpretation of the collected data and additional research into visualization in management to prepare more detailed practical recommendations and to be able to make generalizations from the results obtained. In our work we tried to demonstrate that visual templates for creating business models and solving business problems have huge potential to simplify information processing, and we anticipate more research on the topic.

An approach based on using business model templates may become an effective tool for assessing a business's potential before a business plan has been formally developed. This methodology is widely applicable both for new enterprises as well as established businesses, for-profit and non-profit organizations, and for adjusting business strategy or planning entry into new markets. Developing a business model based on a mind map requires relatively little time. This tool makes it possible to assess and compare many potential representations of a business model, which makes it a highly effective tool for maintaining a company's activities in the long-term and for monitoring the business environment amid conditions of rapidly changing markets and explosive high-tech growth.

Through the exchange of ideas, the described tool helps maintain an atmosphere that fosters creativity in a company, which is especially valuable during brainstorming when every person has the opportunity to put forward his or her ideas, share them, and be heard and understood by the other participants of the process. After creating several mind maps company management may select an option, choose priorities, define the stages of implementation, and meet the needs for any given resource at the different planning stages. In combination with modern mind-mapping software, visual business modeling has significant potential to simplify the development of business models and reduce the time between conceptualization and implementation. 

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