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The wild cards conception as an element of foresight studies has been widely discussed by numerous scholars who have interest and qualification in strategic management field or STI policies from the end of the previous century. Some researchers focus their attention on the general key features of this phenomenon and its overall impact as well as origin, while others study possible applications of wild cards analysis in corporate and government sectors. The purpose of this research is to systematize knowledge about wild cards, determine their role in foresight practices and suggest an instrument for their detection and implementation into foresight research. For this reason, on the basis of a number of national and international foresight projects, we developed existing methodological approaches of wild cards identification, analysis and visual presentation. The results of the study were applied to Russian S&T Foresight 2030.

JEL Classification: O32.

Key words: foresight, national foresight projects, wild cards, weak signals, STI policy

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1. Introduction

It is common knowledge that people always try to predict future so as to decrease the extent of its uncertainty and prepare for the most surprising and earthshattering events (Petersen, 1997). However, foresight practice which includes technology forecasting, futures studies, future-oriented technology analysis and forward-looking activities has begun to spread in public and private sectors only since the mid-1940s (Andersen & Andersen, 2014). Before that time, according to Jemala (2010), there was an era of forecasting which is completely different from foresight. The latter, in contrast to the former, has a less deterministic approach (contains multiple plausible options of future instead of one predicted pathway), richer methodological toolkit (a number of complementary qualitative and quantitative methods) and more inclusive environment (diverse groups of people with different viewpoints about the future) (Saritas & Burmaoglu, 2015). The reason for this shift is thought to be the onset of the second phase of globalization which can be characterized by strengthened mutual interconnections and accelerated technological progress and includes several World Wars, the Wall Street Crash, the Great Depression, oil and energy crises, ICT boom and other meaningful events (Jemala, 2010).

These circumstances made people reassess the way they try to predict future and prepare for the radical changes and at the end of the previous century, with the onset of the third phase of globalization, scholars introduced a concept called "wild cards" which broadly speaking means any surprising events (Steinmuller, 2004). This concept, being a part of the first generation of foresight, became prevalent among scientific and business communities, especially futurists, strategists and risk managers (Saritas & Smith, 2011). Considering this issue in more detail, some other researchers specified the term and developed the concept by adding new elements to it, particularly "weak signals" which sometimes are thought to be the precursors of wild cards (Saritas & Smith, 2011; Popper, 2012). However, these events still present the core of the concept and attract the main research interest which leads to the first research question:

RQ 1: What are the most distinguishing features of wild cards and how can they be classified?

In this light, numerous foresight studies were conducted at global, national, international, regional and corporate levels (Milshina & Vishnevskiy, 2018; Sokolov & Chulok, 2016; De Spiegeleire et al., 2016; Gershman et al., 2016; Rijkens-Klomp & Van Der Duin, 2014; Kindras et al., 2014; Delaney & Osborne, 2013; Chong et al., 2011). This paper investigates 6 foresight studies that include the analysis of wild cards which are: Risk Assessment and Horizon Scanning

(RAHS) conducted in Singapore (Williams, 2012; Chong et al., 2011), The Australian Joint Agencies Scanning Network (AJASN) formed by Australia and New Zealand (Delaney & Osborne, 2013; Williams, 2012), Sigmascan (UKSS) based in the UK (GOV.UK, 2018; Williams, 2012), Metafore (Meta) established in Denmark (De Spiegeleire et al., 2016; Williams, 2012), iKNOW originated in the EU (iKNOW, 2013) and Russian S&T Foresight 2030 (Gokhberg, 2013). These projects were compared by purpose, duration, methods and results. The comparison is used to emphasize the variety of roles which this analysis plays in different countries: sometimes it is conducted in order to formulate adequate STI policy for government, while in other cases it is done for business companies to adopt their corporate strategies in accordance with changes of paradigm (Williams, 2012). The second research question, therefore, arises

RQ2: What is the role of wild cards analysis in national foresight projects?

Paying special attention to the methods used in the abovementioned projects, a list of the most popular tools was compiled as well as the effectiveness of their application was studied. On this basis, the main advantages and disadvantages of each method are discussed. As practice shows, the most time-consuming and labor-intensive techniques are horizon scanning and scenario planning since they are designed to study the long-term period (Jackson, 2013). Less time-consuming but still labor-intensive and rather expensive are modelling, clustering and data analysis procedures because they require high expertise and advanced software (Jackson, 2013). Expert procedures, in turn, appear to be less sophisticated and more productive but have a higher risk of bias (Jackson, 2013). This raises the third research question: what methodological toolkit can be used for wild cards detection and incorporation into foresight projects at the national level?

To answer these questions a number of theoretical and empirical studies were analyzed, in particular, one of the most large-scale projects of Russia in S&T long-term foresight area The four cycles of its development were identified and the place of wild cards analysis in each of them as well as the basic methods for their discovering were determined. As a result the authors create a special analytical instrument – Radar for wild cards detection – and demonstrate its application to 7 S&T areas (ICT, Medicine, Biotechnologies, Environment, Space, Energy, and Transport) and the machinery industry. Finally, possible applications of this instrument are provided and directions for further research and practices discussed.

2. Literature Review

2.1. Definitions and Key Features

The term "wild card" has become widely known when the report "Wild Cards: A Multinational Perspective" prepared by Rockfellow (1994) and his colleagues was published. According to this report, wild card is an "event having a low probability of occurrence, but an inordinately high impact if it does" (Rockfellow, 1994). In the 20th century he pointed out the creation of nuclear weapons, computers and artificial satellites along with the first and second World Wars as the main wild card events. Almost the same understanding of wild cards was shared by Petersen (1997), who defined them as "low probability, high impact events that happen quickly".

After that, most scholars used this original definition, but considered the impact in terms of changes in the organizational structure of a company or ways its business is conducted (Mendonça et al., 2004; Smith & Dubois, 2010). Such an approach, as Steinmuller (2003) argued, missed a central point of wild cards' characteristics: these events not only have high impact, but change completely the concept of ordinary world and normal way of things. Apparently, this interpretation was taken into consideration by Saritas and Smith (2011), who noted that wild cards "tend to alter the fundamentals, and create new trajectories" which can include either additional challenges or opportunities for stakeholders. Thus, these events are usually treated with either extreme optimism or pessimism, but more often they are thought to be "serious, destructive, catastrophic or anomalous" (Mendonça et al., 2004).

In a similar way, the concept of "weak signals", strongly connected with the wild card concept, has being developed since the end of the previous century, when the famous mathematician and economist, Ansoff (1984), offered to use it in strategic management in order to predict future changes in business environment. Being provided with the only basic definition of weak signals as "symptoms of possible change in the future", scholars continued to develop it: some of them described these symptoms as events which importance is merely noticeable at the time of occurrence but increases significantly in future, while others characterized them as ideas or trends that can affect business environment in an unexpected way and, therefore, pose a threat or an opportunity for a company (Coffman, 1997; Kamppinen et al., 2002).

In this regard, weak signals can be easily confused with wild cards, the difference between which was highlighted by several scholars (Holopainen & Tovoinen, 2012; Popper, 2012; Smith, 2011; Mendonca, 2004). As it was noted by Mendonça and his colleagues (2004),

weak signals only present the scattered data that point to the possibility of wild card's emergence, but not to its confirmed transformation into strong signal and, finally, wild card. This statement was also confirmed by Holopainen and Tovoinen (2012) who showed that a clear distinction between the sign of a phenomenon and the phenomenon itself as well as a weak signal and wild card exists. Taking this fact into account, Popper (2012) specified the definition and argued that advance intelligence about future events, including wild cards, can be obtained from them. Saritas and Smith (2011) provided such examples of weak signals as the first mention of global warming and climate change in 1980s and the first book about nanotechnology written by Drexler and published in 1986.

The key features of both wild cards, or surprising events, and weak signals, or warning signs, are presented in the table below.

Tab. 1. Key Features of Wild Cards and Weak Signals

Main features	**Wild Cards**	**Weak Signals**
Probability and occurrence	• Have low probability of occurrence (Rockfellow, 1994; Petersen, 1997; Steinmuller, 2003; Mendonça et al., 2004; Smith & Dubois, 2010)	• Have little importance at the time of occurrence and a substantial lag time before becoming a mainstream (Coffman, 1997; Kamppinen et al., 2002)
Consequences	• Have high impact and immediate strategic consequences for an organization or society (Rockfellow, 1994; Petersen, 1997; Mendonça et al., 2004; Smith & Dubois, 2010)	• Predict future changes /strategic discontinuities/ paradigm shifts/ developments in technologies, societal, innovations, conflicts (Ansoff, 1984; Saritas & Smith, 2011; Popper, 2012)
Potential for detection	• Do not fit into the usual frame of reference and change the concept of the ordinary way of things (Steinmuller, 2003; Barber, 2006; Saritas & Smith, 2011)	• Constitute raw informational material (unstructured, fragmented, incomplete and inadvertent bits of information) for enabling anticipatory action (Ansoff, 1984; Saul, 2006; Saritas & Smith, 2011; Mendonça et al., 2012)
Impact	• Considered as serious, destructive,	• Hidden among the "noise" of the

	catastrophic or anomalous events (Steinmuller, 2003; Mendonça et al., 2004; Saritas & Smith, 2011)	prevailing sense making paradigm and not easily verifiable from a present day perspective (Coffman, 1997; Saul, 2006; Saritas & Smith, 2011)

2.2. Classifications

Taking into consideration the scope of features of wild cards as well as weak signals, which might predict their emergence, the classifications of the former are described in the following.

A number of scholars provided different classifications, starting with Meristö (1991) who identified five categories of wild cards on the basis of the context of their emergence: socio-cultural, technological, economic, environmental and political (STEEP). Next Steinmuller (2003) suggested five ways of classification of these events in accordance with their topic (STEEP), impact (more and less potent wild cards), plausibility (more and less probable, possible and impossible wild cards), time-scale (short-term, or sudden, and long-term, or creeping, events) and causes (a coincidence or a result of a long-term processes). The classification of plausibility was expanded by Mendonça and his colleagues (2004) who determined four types of wild cards: imaginable surprises, unimaginable surprises that are probable, unimaginable surprises that are improbable and certain surprises. This classification is similar to the categorization of "black swans" which can be subdivided into unknown unknowns (unimaginable surprises), unknown knowns (imaginable surprises), and events with negligible probability (certain surprises) (Aven, 2015). At the same time, van Rij (2013) regarded black swans as one of the types of wild cards along with the "accidents and catastrophes" and "growth of tension". Moreover, the break type classification was offered which means wild cards differentiation by their impact on the development of the society that can be either long-term or short-term accompanied with a positive or negative trend (Mendonça et al., 2004). Finally, delayed and immediate as well as total and local wild cards were identified in terms of time and geographical space of their influence (Smith & Dubois, 2010).

Combining the abovementioned classifications, Smith and Dubois (2010) created a block scheme which presents all of them. However, it seems that some other classifications important for the analysis of wild cards were omitted. For example, Hiltunen (2006) divided wild cards into reversible and irreversible ones which emphasis the significance of consequences that these

events can have. Furthermore Barber (2006) offered a more detailed classification of these events in terms of their impact: it can be not only local or total, but personal, national, transnational and international as well. In addition, Petersen (1997) added one more type of wild cards in accordance with their topics, or areas of life, – spiritual and paranormal events. Hence, we combined these classifications and included them into the table below. The cells of the table marked with red and yellow colors mean that these types of events totally or partly contradict the key features of the concept discussed earlier and, therefore, cannot be fully considered as wild cards.

Tab. 2. Classification of Wild Cards

Consequences (Hiltunen, 2006)	Reversible	Irreversible				
Process (Steinmuller, 2003; van Rij, 2013)	Long-Term (Creeping Catastrophe)	Sudden (Hollywood-Style)	Black Swans			
Plausibility (Mendonça et al., 2004)	Highly Certain	Imaginable & Probable	Imaginable but Improbable	Unimaginable		
Break Type (Mendonça et al., 2004)	Dead End	Slow Dead End	Dead End to a Recovery to Trend Line	Push Up in Positive Direction	Slow Push Up in Positive Direction	
Topic (Meristö, 1991)	Military/ Political	Technological	Economic	Socio-Cultural	Environmental/ Biological	
Life Areas (Petersen, 1997)	Surprise Attack	Technology & Infrastructure Upheaval	Earth & Sky	Geopolitical & Sociological Changes	Biomedical Developments	Spiritual & Paranormal
Impact (Barber, 2006)	Personal	Local	National	Transnational	International	Global

Do Not Contradict

Partly Contradict

Fully Contradict

Despite such a variety of types of wild cards, they have common features which determine their influence on the society: a profound impact on the human condition, far-reaching implications and an extremely high speed of diffusion for the whole system to adjust to it (Petersen, 1997).

1. Wild cards create new challenges for the future that form the agenda for research and development, innovation, socio-economic, environmental and security policies (van Rij, 2013).

2. These events undermine current trends and make us reassess our past by forming a new picture of future, changing our awareness of it and generating new concepts (working as early warning systems) (Steinmuller, 2003). In this way wild cards were compared by Steinmuller with bifurcations in the chaos theory which "mark the beginning of new developments, diverging evolutionary paths" (Steinmuller, 2003).
3. Weak signals, in turn, sometimes strengthen and transform into strong signals and, finally, mainstream that can be considered as a reference point of new trends and megatrends (Holopainen & Tovoinen, 2012). Some scholars even believe that weak signals can predict the emergence of wild cards (Cooper et al., 2011).

Accordingly it becomes clear that the analysis of weak signals as well as wild cards should be conducted at an organizational, country, cross-country and global levels. Generally speaking, these wild cards as elements of foresight analysis help people to "stretch" the paradigm, that is to consider the alternative points of views, to "expand" it which means to accept the need of taking into account various perspectives and possibilities and to "crack" it or fully replace the traditional one by the new one (Barber, 2006). In more specific terms, the wild cards analysis helps entities to:

- adopt the policies to sudden changes and improve their sustainability;
- estimate the possible damage or benefit and prevent or multiple it in advance;
- increase the amount of investments in security measures (e.g. to organize a monitoring system, to construct dams in case of a flood or strengthen a building in case of an earthquake, to prepare evacuation routes etc.);
- counteract to undesirable anthropogenic "cards" such as terrorist attacks, revolutions and so on (van Rij, 2013).

Overall, predicting imaginable wild cards can be an effective activity for making preventive decisions in order to ensure the organizational resistance to external influences and influence the direction of future development (Petersen, Steinmuller, 2009). As it was noted by Mendonça et al (2004), the analysis of wild cards reduces the time of crisis management reaction and increases the possibility of choosing a right action. The same role can be attributed to the weak signals' analysis since in both cases a special knowledge about the organizational environment is obtained (Mendonça et al., 2004).

2.3. Identification of Wild Cards in National Research Projects

The scope of foresight methods, including ones for wild cards identification in national research projects, was described in detail by Miles et al (2017). This scope is organized according to the eight phases of foresight activities: initiation, intelligence, imagination, integration, interpretation, intervention, impact and interaction. Apparently, the analysis of wild cards is most suitable for the imagination phase since this process requires a great amount of creativity to imagine the most surprising events (van Rij, 2013). In this regard the most appropriate methods for the identification of these events involve scenario planning, modelling, systems mapping and Delphi. Some of these methods were also explained by Ponomareva and Sokolova (2015) who studied the analysis of weak signals which is tightly interrelated with the wild cards uncovered. For example, expert panels, interviews, workshops and Delphi being "the most common among foresight technologies" are conducted in order to collect, validate and interpret all the information which indicates possible wild cards (Ponomareva, & Sokolova, 2015). At the same time modelling and clustering data are needed to create an adequate model for the analysis and compile relevant sample of documents. The horizon, or environmental, scanning, in turn, is used for identification of external and internal potential benefits and challenges which can be important for a particular company or an area. Moreover, intellectual data analysis, for example, text mining is capable not only of obtaining and analyzing the information about wild cards, but evaluating risks of their emergence and developing appropriate strategies as well.

The majority of national foresight projects analyzed is based on the horizon scanning as one of the main instruments of wild cards prediction, but the elements of other methods are also included and will be discussed further. As it was noted by Ponomareva and Sokolova (2015), the combined usage of these methods is more effective than their separate application.

In accordance with the report of Forward Looking Activities, prepared by Williams (2012), there are five national Horizon Scanning (HS) projects which regularly monitor the environment and detect wild cards:

- RAHS was developed by the Singapore Government Horizon Scanning Centre in 2004;
- AJASN was formed of four government agencies in 2005, but now include 22 different state agencies from Australia and New Zealand;
- UKSS was started by the UK Government's Horizon Scanning Centre in 2005;
- "Meta" was set up by the Hague Centre for Strategic Studies in 2007;

- iKNOW was launched by the European Commission as a part of its 7th Framework Programme for Research and Development in 2007.

Regarding the goals and objectives of these projects, the RAHS programme was created in order to complement the scenario planning processes through data collection and classification, relationships' analysis and emerging issues' discovering that "could have a strategic impact on Singapore" (Williams, 2012). Having set such a broad aim, the Singapore Government Horizon Scanning Centre divided its activities into three main blocks: research and analysis which involves the examination of signals "collected from the environmental scanning"; perspective-sharing which means the analysis of the information obtained "for convergence and divergence as well as for possible outliers or even wild cards"; modelling that is building ranking models and creating system maps, assessing strategic options and scenarios (Chong et al., 2011).

For each block a suite of technology-based methods and tools was developed, such as advanced data analytics, text analytics, computational modelling and pattern analysis. For instance, the perspective-sharing analysis of wild cards consolidates the perspectives and insights of external stakeholders and visualizes them through system maps and perspective models (Chong et al., 2011). Nevertheless, the human-based methods are also being used in the RAHS. The members of the Centre regularly organize International Risk Assessment and Horizon Scanning Symposium, invite experts in this field from other countries, attend conferences related to the foresight topics and discuss them during the workshops. The results of the analysis are usually presented in "a very brief daily scan product which is distributed to 3000 civil servants" because policymakers have time to read only short summaries with the main ideas (Williams, 2012).

Another foresight project, the AJASN, which detects wild cards as a part of its activities was set up to provide advance intelligence of future changes that could be significant for health departments in Australia and New Zealand through the information exchange between them (Williams, 2012). According to Delaney and Osborne (2013) this business model is rather unique because of the "fluid partnership" created by national agencies of two countries. With the expansion of the network its activities reoriented towards a wider range of subjects from space and environment to industry and economics (Delaney & Osborne, 2013). Along with the agencies from those two countries, the AJASN has strong external links with universities and research groups, national public and non-profit organizations.

As Williams (2012) points out, the only method of wild cards analysis in this approach is the focused expert interview. The AJASN has a database which contains more than 10000

articles and other media and "grey" literature (e.g. reports, studies and monographs). This database is regularly updated and quarterly reviewed by the members who, in accordance with "the rule of thumb", assess the importance of different scan "hits" and identify the anomaly (Delaney & Osborne, 2013). As a result, quarter and annual reports are produced by the AJASN. Currently on its official web site there are three newsletters connected with geopolitics (December 2017), agriculture (February, 2018) and public service (March, 2018) (The Australasian Joint Agencies Scanning Network, 2018).

In the same year the Sigma Scan project was launched which purpose was to help government policy-makers identify factors affecting long-term decisions and prevent accidents, such as wild cards, happening (Williams, 2012). So as to realize the project the UK Government's Horizon Scanning Centre collects data from more than 6000 sources that include scientific journals as well as futurists' blogs and interviews with the most distinguishing thinkers. Next this information is "condensed into unique insights" by the experts that makes it similar to the previous approach (the AJASN) which is also based completely on the experts' opinion (Williams, 2012).

The output of that project is a set of brief papers (around 250) which explore the potentially significant issues and trends, including wild cards, over the next 50 years for the UK. As well as the AJASN this project covers a wide range of subjects, including sciences and humanities and can be used in workshops and other projects "to promote better awareness of different potential futures in government policy-making" (Williams, 2012). However, at the moment there are only five papers presented on the official web site which dates back to 2016 (Artificial intelligence) and 2014 (Emerging economies, Emerging technologies, Resource nationalism, Social attitudes of young people) (GOV.UK, 2018).

One more project was started in Europe two years later, Metafore, which is aimed at the collection, processing and visualization of different foresight studies in multiple languages, specifically, English, French, German, Russian, Chinese, and Turkish) (Williams, 2012). Such a variety of studies was chosen in order to reflect both Western and Eastern views, developed and developing countries' approaches as far as the latter are going to play a significant role in future global security environment (De Spiegeleire et al., 2016). Another goal of this study, therefore, was to "to map the bandwidth of views about the future in various policy areas" (Williams, 2012).

The projects' database is being updated regularly and now contains more than 4000 studies. To exclude the expert bias that is an integral part of the previous two projects (The

AJASN and Sigma Scan) and overcome the "failure of pundits" a collective opinion, or "wisdom of crowds" was used in a semi-automated approach (Williams, 2012). This approach means the usage of web-crawling and text-mining as the main instruments of wild cards analysis. A special software was developed for this purpose, which is called "Sema-Dyson" – a programme that constantly monitor a number of foresight-relevant online sources (e.g. Google News, EU Media Monitor etc.) using targeted searches such as "wild cards", "trends" and "scenarios". Simultaneously the Chinese, Russian Arabic and English studies are being scanned manually because of the high labour intensity of this process which requires the identification of cultural differences (De Spiegeleire et al., 2016).

Another European project is iKNOW, which is targeted to interconnect the existing knowledge about the current issues and future developments, especially technological and innovational ones, affecting Europe and the world (iKNOW, 2013). According to the description of the project on its official web site, it has two interrelated objectives: to create the methodological and conceptual frameworks for the wild cards and weak signals analysis and to identify the possible impact of these phenomena (iKNOW, 2013). The team of this includes eight partners highly experienced in the foresight field and STI policies among which are the Manchester Institute of Innovation Research, Finland Futures Research Centre Interdisciplinary Centre for Technological Analysis and Forecasting etc..

The iKNOW database, or iBANK, at the moment contains 437 wild cards and 353 weak signals which were extracted from numerous literature reviews, workshops and scanning projects funded by European Commission as well as websites, blogs, journal articles and official reports. These two strategies of searching for information inside and outside the European research space were developed by the members of iKNOW Consortium and helped them to uncover more than 700 "surprising and interesting issues" (iKNOW, 2013). Moreover, the interview-based procedures are being conducted in a form of moderated discussions of experts invited from the Scenario Building and Roadmapping panel. The selection of these experts is usually based on STEEPVL (social, technological, economic, environmental, political, value-related and legal) dimensions which allow conducting the analysis in a more complex way (Koloniuk & Magruk, 2015).

On the basis of the main methods of wild cards detection (Ponomareva & Sokolova, 2015) and the main foresight projects, mentioned by Williams (2012), which use them partly, the table below was compiled.

Tab. 3. Methods of Wild Cards Analysis in National Research Projects

Methods / Project	Horizon Scanning	Scenario Planning	Modelling & Clustering	Expert Panels	Delphi Surveys	Text-Mining	Bibliometric and Patent Analysis
RAHS	+	+	+	+		+	+
AJASN	+			+			
Sigma Scan	+			+			
Metafore	+		+	+	+	+	+
iKNOW	+	+		+	+		+

Note: '+' means that the method appears in the Foresight study

However, some projects were omitted in the William's study. For example, a National Intelligence Council was created in the USA in 2002 which's core mission is to provide a new coming President with a full report of global trends in the next 20-25 years (Office of The Director of National Intelligence, 2018). The Council integrates the intelligence of National Counterterrorism Center (NCTC), the National Counterproliferation Center (NCPC), the National Counterintelligence and Security Center (NCSC), and the Cyber Threat Information Integration Center (CTIIC) and identifies central trends and wild cards via expert procedures. The latest report was released in 2017 and contains two wild cards: the fast-growing economies of China and India.

Furthermore, in the EU the European Strategy and Policy Analysis System (ESPAS) was set up in 2010 to identify global trends and potential shocks, or wild cards, nourish strategic thinking in EU institutions, involve academics, think tanks and other stake-holders to provide a broader perspective, develop international links and attract foreign expertise (European Strategy and Policy Analysis System, 2018). Special inter-institutional working groups were created for writing the reports on these issues in three key fields: economy, society and governance.

Another European project in the foresight field which includes wild cards analysis is the Dahrendorf Forum, initiated in 2015 that takes a closer look to five main regions and countries: China, the Middle East and North Africa (MENA), Turkey, North America, Russia and Ukraine (Dahrendorf Forum, 2018). The international experts on these regions and policy makers identify and discuss drivers and barriers, wild cards and weak signals that affect the future changes in the relationships between the European Union and those regions and countries. After that, the

experts develop different scenarios taking into consideration possible risks, new trends and opportunities.

Thus, it can be concluded that horizon scanning and expert procedures are the most prevalent ones among national foresight projects, but these methods are not devoid of shortcomings as well. The benefits and limitations of each approach, according to Jackson (2013), are presented in the table below. Some approaches combine such procedures as text-mining and bibliometric and patent analysis in one category – data analysis procedures - as well as expert procedures which include expert panels and Delphi surveys because of numerous similarities between them (table 4).

Tab. 4. Benefits and Limitations of Methods of Wild Cards Identification

Method	Advantages	Disadvantages
Scanning & Planning	• Detects anticipatory warnings (weak signals) • Provides time to prepare for wild cards • Helps to analyze a wide range of issues and generate a common understanding of them • Deals with complex uncertain environments	• Involves a lot of time and human resources • Requires advanced technology-based tools • Lacks creditability for the long-term period • Can be followed by "incorrect" interpretation
Modelling & Clustering	• Predicts the behavior of complex systems in dynamic environment • Easily manageable because of pre-defined structure of the design and set of rules	• Requires safe environment • Has numerous premises and limitations
Expert Procedures	• Provide fast feedback • Help to analyze a wide range of issues • Combine convergent and divergent (out-of-the-box) thinking • Allow to reach a consensus ("crowd wisdom")	• Include expert's bias • Involve a lot of time and human resources • Lead to destructive intragroup disagreements

Data Analysis Procedures	• Process large quantities of structured and unstructured data and develop indicators of change • Handle many intermediate links • Identify the extent of probability and uncertainty, varying durations • Present ways of risks' minimizing and alternative routes	• Require high expertise and training • Need sophisticated software and access to advanced databases • May miss important sources or key words • Should be validated by experts

Several conclusions can be drawn from the table above. To start with, despite all the benefits of Delphi surveys, expert interviews and workshops, they still contain some type of bias and subjective opinion which can affect the results of the analysis significantly since wild cards, according to their key features, do not fit into the usual frame of reference, or paradigm. Thus, some other participants of Forward-Looking Activities (the Singapore Government Horizon Scanning Centre and the Hague Centre for Strategic Studies) try to validate the results of wild cards detection through more reliable technology-based methods such as modelling, clustering and data analysis.

These methods, in turn, are usually rather costly because of the software needed for the process and qualification of the personnel who manage this process. For this reason there are many national foresight projects that do not include these methods and invent other instruments of validation. For example, the AJASN uses regular peer-reviewing of information obtained and wild cards suggested which decreases the risk of an important signal or area been missed and the expert been mistaken (Delaney & Osborne, 2013). iKNOW as well as ESPAS involve academies, universities, think tanks, foreign partners and other stakeholders in these activities to broaden the limitations of the study, increase the scope of experts and diversify the results, particularly wild cards. The same instrument is being used at the Dahrendorf Forum where representatives of different countries can express their opinions about future shocks.

2.4. Identification of Wild Cards in Recent Studies

Regarding the most recent research projects which were conducted in this area, it is important to note that during the previous year the largest number of future studies dedicated to the wild cards detection was carried out. According to the bibliometric statistics represented at the figure below (Figure 1), similar peaks of publication activity on this topic were observed ten and four years ago. The statistical data was obtained from the citation database "Web of Science" by means of the following search requests: "wild NEAR/0 card$", "(wild NEAR/0

card$) AND (weak NEAR/0 signal$)", "(wild NEAR/0 card$) NEAR (foresight* OR future*)", "(weak NEAR/0 signal$) NEAR (foresight* OR future*)".

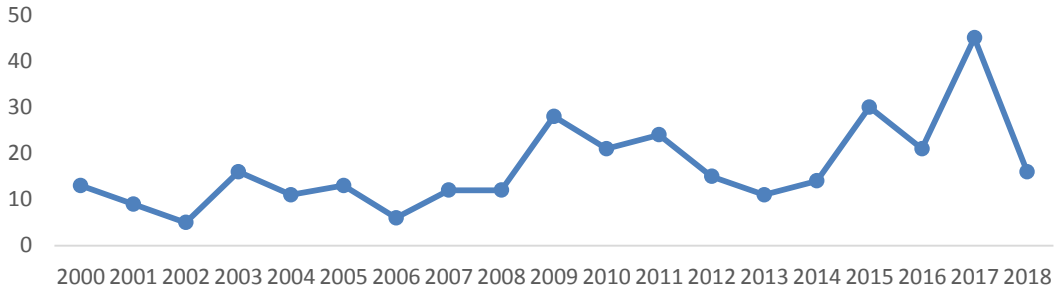

Fig. 1. Bibliometric Statistics (2000-2018), number of publications.

In contrast to the national research projects connected with the detection of wild cards which are of vital importance for the sustainable socio-economic development at a country level, the recent future studies in this area are mostly focused on the economic analysis of potential surprises in particular industries, for example, energy (Heinonen et al., 2017), logistics (Magruk, 2018), and e-commerce (Qi & Tapio, 2018). At the same time other studies involve the analysis of wild cards which might occur after the mass adoption of such technologies as the Internet of Things (Tzezana, 2017), nanotechnologies and new materials (Vishnevskiy & Yaroslavtsev, 2017), smart grids (Park & Cho, 2017) and photovoltaic technologies (Moro et al., 2018). Moreover, some of the studies address one of the most topical social, environmental and political issues such as new kinds of terrorism, for instance, high-tech terrorism (Steinmuller, 2017; Tzezana, 2017), water resources, utilities and sanitation (Saritas & Proskuryakova, 2017; Takala & Heino, 2017) and resilience awareness (Grigoraș, 2018).

Despite the differences in scale and focus of these studies, in comparison to the national studies, the methodology in both cases is quite similar: the most prevalent methods are qualitative and semi-quantitative ones such as literature review of the results of the previous studies, newspapers and magazines (Magruk, 2018; Takala & Heino, 2017), expert panels, including expert and consumer Delphi surveys, (Qi & Tapio, 2018; Tzezana, 2017) and horizon scanning (Qi & Tapio, 2018; Saritas & Proskuryakova, 2017). Some of the authors have also employed a combination of these methods using the STEEP/STEEPVL framework for the identification of global trends, weak signals and discontinuities along with wild cards (Qi & Tapio, 2018; Heinonen et al., 2017; Saritas & Proskuryakova, 2017; Vishnevskiy & Yaroslavtsev, 2017) as well as cross impact matrixes and expert panel matrixes (Qi & Tapio, 2018; Heinonen et al., 2017). Finally, some scholars applied only quantitative foresight techniques such as text mining and bibliometric analysis (Park & Cho, 2017; Moro et al., 2018).

3. Wild Cards Detection

In this study the analysis of wild cards is being carried out as a part of the national long-term foresight of S&T development (S&T Foresight) sponsored by the Ministry of Education and Science of Russian Federation (Sokolov et al., 2013).

The first cycle of national S&T Foresight in Russia dates back to 2006-2007 years, when a long-term S&T Foresight in Russia for the period up to 2025 year was launched. This project consisted only of three main parts: macroeconomic, S&T and industrial sections. In the first part a basic scenario of economic development of Russia was described, while in the second part the most prospective technologies in 10 main fields of S&T were uncovered using a large-scale Delphi survey conducted among 2000 experts, whereas in the third part 6 key sectors of Russian economy were analyzed and the tendencies for long-term development were identified as well as demand for new technologies was projected. Among these new trends and demands several wild cards were mentioned: the rapid development of nano-industry and pharmacogenetics, creation of new convergent technologies and improvement of human's consciousness and body with the help of electronic implants and physical modifiers (S&T Long-Term Foresight of the Development of Russian Federation, 2008). However, the concept of wild cards was not introduced in this cycle.

The second cycle of S&T forecasting in Russia started in 2008-2009, when a long-term foresight for S&T development in Russia for the period up to 2030 was created (Sokolov et al., 2013). That foresight, in contrast to the previous one, contained two more sections: foreign and international forecasts of economic and S&T development, which allowed not only to predict the future of the entire global market and certain main industries, but to build several scenario options of Russia's development. To validate the results of research, some expert procedures were employed and the prospective technology groups and products were clustered to estimate their potential socioeconomic effect. This cycle is interrelated tightly with the first one, because the thematic and S&T areas (ICT, nanoindustry, living systems, natural resources, transport and aerospace, energy), which were previously selected from hundreds of Delphi topics, were used as a basis for the technology clusters' creation. In similar way wild cards were only described in the context of scenarios building (macroeconomic, industrial, S&T and international) but not introduced as a separate element of the Foresight methodology (S&T Long-Term Foresight of the Development of Russian Federation, 2010).

The third cycle of national S&T Foresight was launched in 2011, when the necessity for the update of the previous forecast appeared (Sokolov et al., 2013). The concept of this approach

was changed dramatically: the Foresight was divided into several sections, in accordance with the primary S&T fields, and in each of them global challenges, prospective technology packages, breakthrough innovative products and socioeconomic problems were described. For this purpose a specialized expert panel was formed and the road maps for the innovative development were prepared. Furthermore, a special section connected with the evaluation of the effectiveness of S&T policies as well as methodological base for the usage of the abovementioned road maps in government policies were designed. It is worth mentioning that during this cycle a complex system of global trends and wild cards detection started to develop but the concept of wild cards analysis still was not described and these events were presented as global challenges in the report in 2013 year, for example, the end of Moore's Law and collapse of IT markets (S&T Long-Term Foresight of the Development of Russian Federation, 2013).

The fourth cycle of S&T Foresight in Russia dates back to 2017 year, when its structure was updated and several foresight techniques (e.g. scenarios building and suggestions for policy-making) as well as analysis and validation procedures (e.g. big data and sematic analysis, conferences and seminars) were added to it (Sokolov & Chulok, 2016). Moreover, a special section for the wild cards description appeared in the report of this cycle. The scheme of the organization of both cycles is presented below.

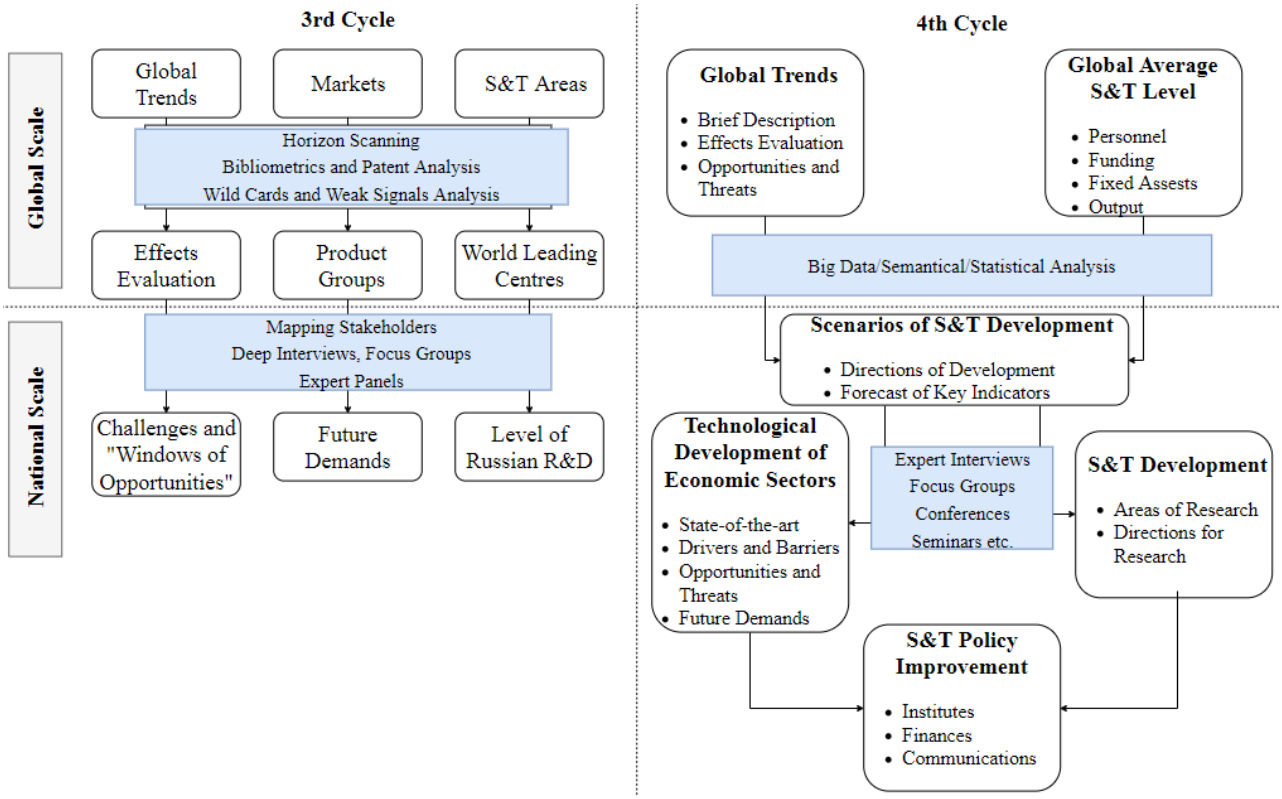

Fig. 2. The Third and Fourth Cycles of Russian S&T Foresight.

As it follows from the Figure 2, the wild cards analysis is included in three simultaneous processes of the 3rd cycle: global trends identification, markets analysis and S&T exploration. Next the effects of global trends are evaluated and the product groups as well a priority R&D tasks are determined. In this regard the wild cards detection plays a crucial role in the evaluation of the scope of the effects, the determination of the right groups of products and S&T areas. Finally, the challenges and "windows of opportunities" are detected and perspective demands assessed for seven priority areas: ICT, biotechnologies, medicine and healthcare, innovative materials and nanotechnologies, environmental sustainability, transport and space systems, energy efficiency and resource saving. Almost the same role the analysis of wild cards play in the 4th cycle: firstly, they are identified with different types of mechanical procedures at a global level and, after that, they are validated by the experts at a national level.

However, in the recent version of S&T Foresight a more extended list of areas was used to identify wild cards. In addition to the abovementioned areas of S&T development the following economic sectors were analyzed: agro-industrial, machine building, metallurgical, chemical, construction and light industries, financial and trade sectors. Overall, in the S&T Foresight 7 technological and 8 industrial spheres were considered and nearly 100 wild cards were uncovered. In addition, the experts estimated the probability and time of occurrence of each event with a planning horizon up to 2050 year. Some other procedures of wild cards detection such as text-mining and big data analysis are demonstrated at the figure below along with different foresight techniques such as describing trends and R&D landscapes, identifying grand challenges and building timelines (lists of events arranged in a chronological order).

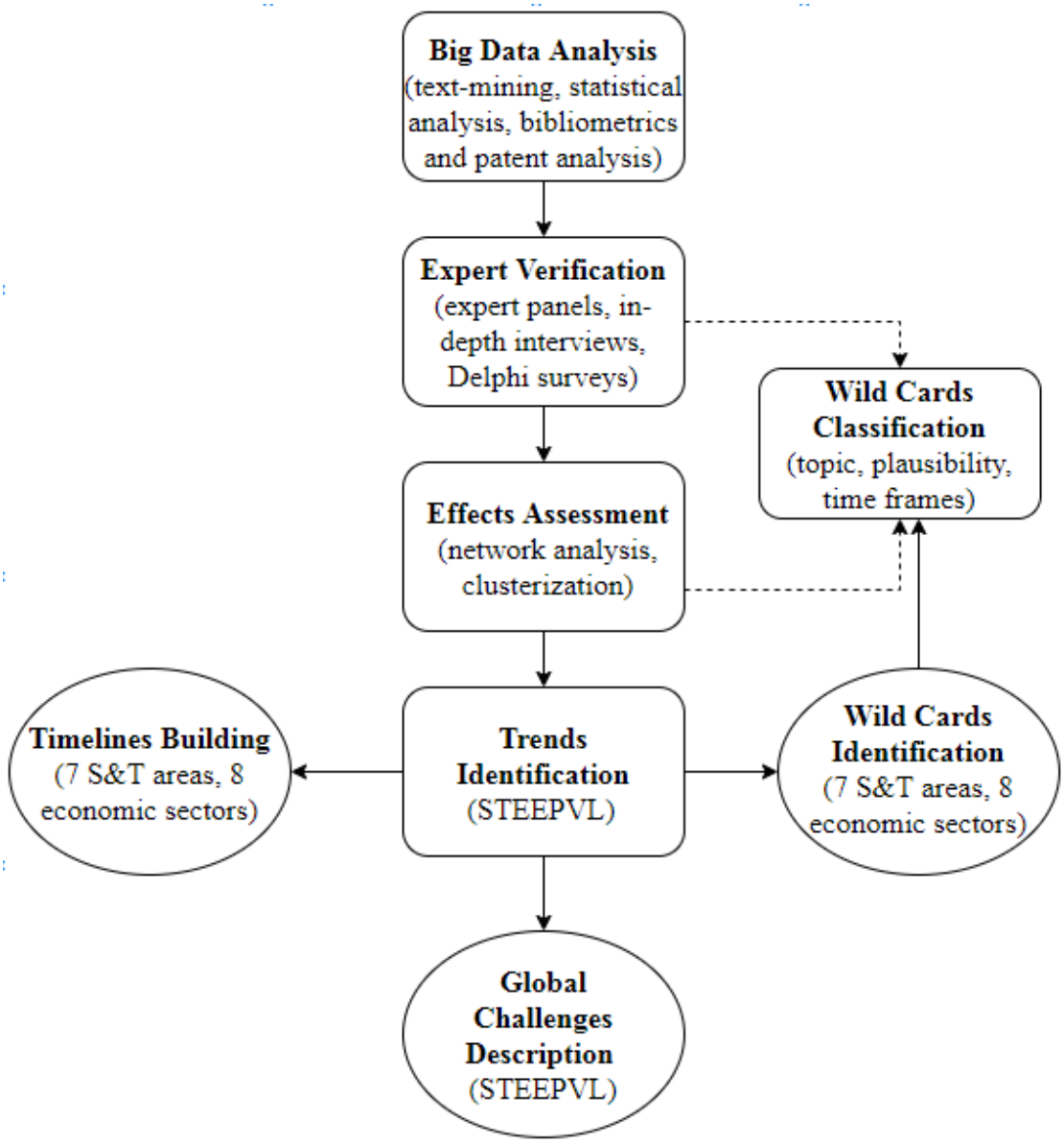

Fig. 3. The Methodology of Wild Cards Detection.

Figure 3 shows that the process of wild cards identification consists of five stages starting from the big data analysis to the trends identification which is the basis for two other procedures such as timelines building and global challenges description. Through all the stages the information about potential wild cards along with key threats and opportunities is transmitted and after it being filtered and validated a set of the most meaningful events is confirmed. In the end these events are being discussed by the experts again but from the point of view of their topic, plausibility and tine frames – parameters which are of vital importance for foresight activities. It is worth mentioning that other features of these events that can be useful to identify (Table 2) as well as their relationships with each other that can be either synergetic or conflicting, as it was noted by Hauptman and his colleagues (2015), are currently not being considered.

Also this figure shows that the main feature of this methodology is a balanced combination of quantitative and qualitative, objective and subjective methods described in Table 4: along with the big data analysis, the expert verification and effects assessment are also being administered. For the first stage of analysis a special intellectual system is used (iFORA), which allows to analyze over 30 million relevant documents in English and Russian languages (articles, patents, forecasts, grants, analytical reports, market surveys, media, social networks, etc.) and map technological trends, assess their significance, track structural changes and prospective directions of R&D. It also provides an opportunity to identify emerging markets, generate forecasts, evaluate the quality of technologies, products and services, weigh policies and even conduct a reputation analysis of companies. At the next stage the experts represented in the scientific and business communities or public authorities are involved in the in-depth interviews or Delphi surveys which are handled in several rounds for the higher accuracy of experts' assessments.

Another distinctive feature of this methodology is a comprehensive view of the areas which are the most significant for the world community in general and each state in particular: society, technologies, environment, economics and politics. These areas are taken into consideration at the fourth stage of wild cards detection – trends' identification – and two more areas are added at the fifth stage – global challenges' description that can provide valuable information about wild cards. Moreover, the analysis of these events and generation of timelines are done for S&T as well as economic fields which mean that no important signals or events are missed. Thus, this methodology allows tracking changes in social, technological, economic, environmental and political spheres and identifying key threats and opportunities that can have a profound impact on the development of the world, state, S&T and economy at the earliest possible stages.

Nevertheless, this methodology still can be improved by the introduction of advanced text-mining which includes the analysis of texts on the basis of distributional semantics and, consequently, increases the precision of wild cards detection, decreases the necessity of experts' assessment and eliminates the problem of important sources or key words being omitted (Table 4). Moreover, this technique lacks the detailed market analysis that was conducted at the 3rd cycle of S&T Foresight, but excluded from the 4th cycle. The importance of such a procedure cannot be overestimated since markets determine perspective product groups and future demands which strongly depend on and sometimes cause external shocks and changes of paradigm. Finally, the method described in Figure 3 should be more flexible and client-oriented because different stakeholders (government agencies, business companies, scientific organizations etc.)

have different preferences and needs which cannot be satisfied through a unified approach and require practical recommendations which should be unique.

4. Discussion

Summarizing the results of the study, several points should be mentioned. Firstly, the core definition of a wild card is an event which happens suddenly, or surprisingly, and has a profound impact on the present paradigm. Weak signals, according to their key features, can sometimes predict these events as well as other future changes, strategic discontinuities and shifts of paradigm. However, if weak signals are hidden among the noise of the prevailing sense and not easily verifiable from a present day perspective, wild cards are considered to be serious, destructive, catastrophic or anomalous events which are easily noticeable at the moment of their occurrence but hardly can be predicted.

This leads us to the second point: the methods that can be used for wild cards identification. In many national foresight projects a mix of methods is used in order to overcome the limitations of each of them: the big data analysis is conducted so as to prevent the results of the experts' assessments and Delphi surveys being too subjective along with modelling and clustering which can increase the reliability of the research. Moreover, sometimes these methods are employed additionally to scenario planning that gives a comprehensive view of the future development. However, the most popular method is expert procedures as far as the costs of its usage are lower than text-mining or bibliometric and patent analysis.

The same combined approach is inherent in Russian S&T Long-Term Foresight project. The wild cards analysis was not conducted during the first two cycles, but this kind of events was described in such sections as global trends and grand challenges. The complex system of wild cards detection started to develop only during the 3rd cycle and was fully employed in the recent 4th cycle. Some of the events detected during the 4^{th} cycle of Russian S&T Foresight are presented at the figure below. Before this figure was constructed, all the procedures of different stages of wild cards identification (Figure 3) were conducted. First of all, the intellectual system of big data analysis (iFORA) was used in order to uncover the emerging trends and phenomena, speed of their development and importance for the world. On the basis of these results five semantic and maps of scientific and technological development connected with STEEP transformations were built. After that, the results were validated by nearly 1000 experts from the state agencies and ministries, academies, universities and business companies, including foreign specialists. Additionally, 40 expert seminars were held along with 15 international conferences

and the same number of focus groups to assess the effects. Finally, the trends as well as wild cards were identified and fields, time and plausibility of the latter's emergence were determined.

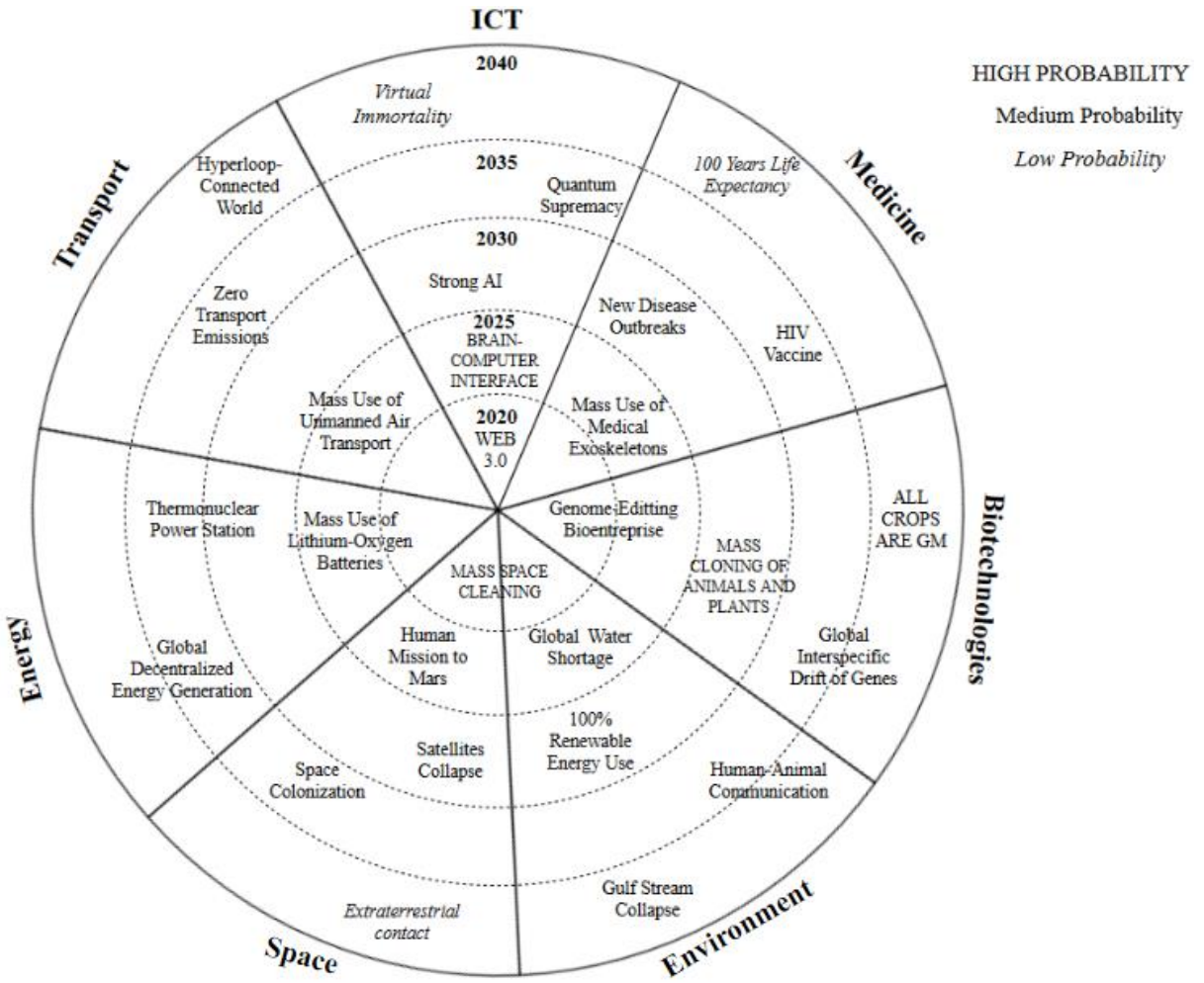

Fig. 4. The Radar of Wild Cards for S&T Areas (Gokhberg, 2013).

As it can be noted, this Radar includes 7 S&T areas of exploration with the horizon in 2040 year and three extents of probability (HIGH, Medium and *Low*). However, these wild cards can also be described in terms of other classifications described earlier (Table 2).

Regarding the reversible and irreversible consequences of this type of events, the Gulf stream collapse, for example, can be considered as a joker with irreversible consequences as it can change completely the climate in Europe and US and cause severe storms and freeze in the former and increase the sea level on the coasts of the latter (The Guardian, 2018). At the same time the mass use of unmanned air transport or lithium-oxygen batteries can be reversible wild cards in case of the introduction of some policies which regulate their usage. It is worth noting, that all these events can be classified as long-term, or creeping, wild cards because the level of global warming and Gulf Stream disruption are being continuously monitored by the environmentalists around the world whereas the development and commercialization of such

new technologies as unmanned vehicles or high-capacity energy-efficient accumulators occurs gradually.

The extraterrestrial contact, on the contrary, can be regarded as a sudden, or Hollywood-style, event, since time of its emergence is totally unpredictable but the emergence itself is being expected by the majority of scientists. For instance, in the USA a special Center for Search for Extraterrestrial Intelligence (SETI) Research was created and a number of projects for the detection of signals from advanced technological civilizations that presumably exist in the galaxy were launched (SETI Institute, 2018). Global satellites collapse is likely to belong to the same class of wild cards since its occurrence can take place in a moment and disrupt all the communications, transport and power systems despite being expected as a consequence of increasing amounts of space waste, whereas new disease outbreaks can even be regarded as "black swans" as far as they are totally unpredictable due to the limits of scientific knowledge and cognitive abilities of people and can undermine the existence of entire species, including human one.

In terms of break type some of the events might have a slow push in a positive direction, for example, a prolonged expectancy of life to 100 years or a world which is connected by a high speed terrestrial transportation system (Hyperloop). These wild cards will certainly improve the quality of people's lives and decrease the number of transport accidents. A similar effect can have a reduction of CO_2-emissions from transport combustion engines to a zero level that can enhance the health of people considerably. However, these break types are slowly positive in contrast to the achievement of "virtual immortality" or "quantum supremacy" or the creation of a strong Artificial Intelligence (AI) or a vaccine from Human Immunodeficiency Virus (HIV) which can have an immediate positive effect on the physical and cognitive abilities of people along with their resistance to one of the most deadly diseases. At the same time the outbreaks of new diseases can be a dead end for humankind, as it was mentioned earlier, while the global shortage of water must be a slow dead end for the Earth and it inhabitants.

Moreover, the wild cards presented on the Radar (Figure 4) can have different kinds of impact from a personal or local one to a national, transnational, international and global one. As it can be noted, most of these events have global impact, for example, human mission to Mars, space colonization, interspecific drift of genes or prevalence of Genetically Modified (GM) crops because they can seriously change the way all people live despite of their age, gender or nation. However, some wild cards can have trans-/international impact, for instance, the destruction of

Gulf stream currents or mass cloning of animals and plants that can affect only certain continents or countries.

At the figure below another set of wild cards is presented with the horizon in 2040 year. This set was compiled using the same methodology of wild cards analysis (Figure 3) but for a special area of interest – machine building industry. Obviously, some events relate to other areas as well, for example, ICT, energy, transport, space, agriculture etc.

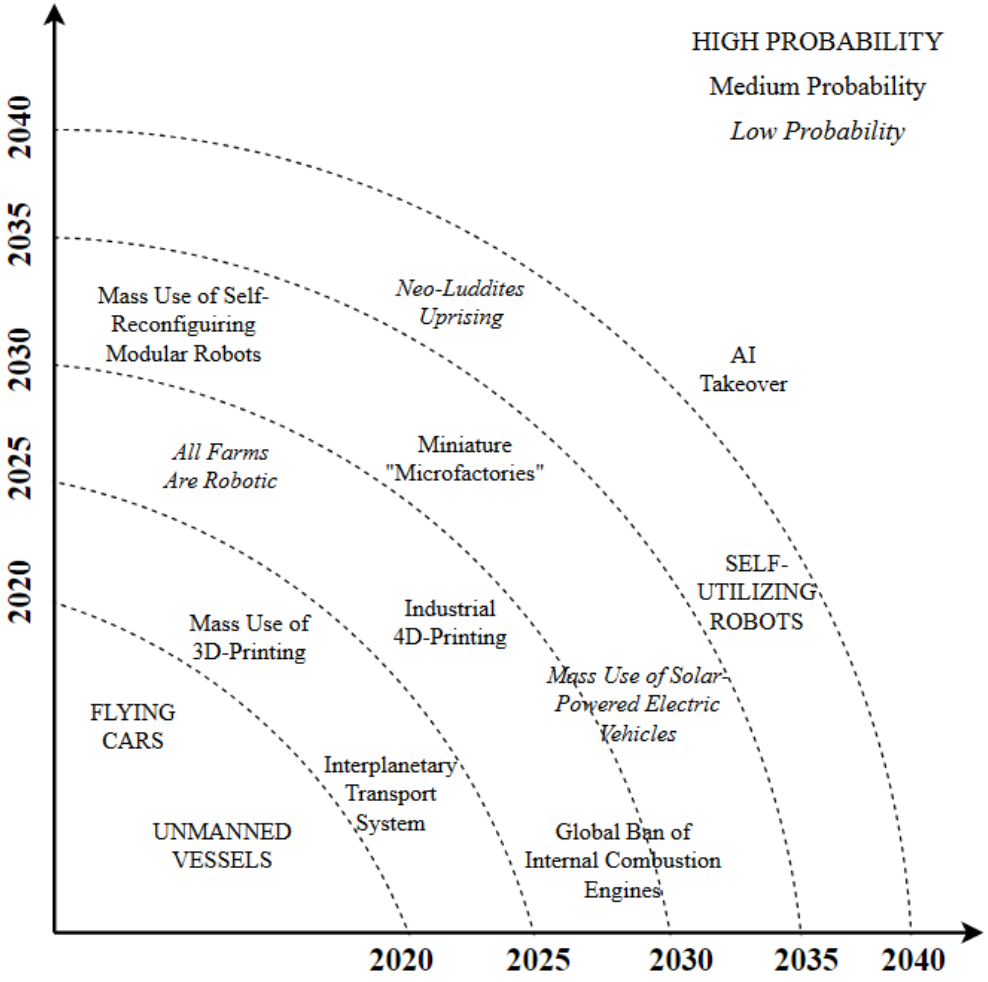

Fig. 5. Wild Cards for Sectors: Machine Building Case (Gokhberg, 2013).

According to this figure, one of the highly probable events which can happen in the nearest 2-3 years and have an earthshattering impact on the present way of live is the first in the world flying car. This vehicle is going to be commercialized in 2020 year by the Slovakia-based company AeroMobil (AeroMobil, 2018). As it follows from the description of its technical characteristics, the car can be driven either on road or in the air with the highest speed of flight about 224kW (300 hp), and human machine interface similar to the pilot's one. Apparently, this kind of transport can replace traditional cars, civil helicopters and personal drones and greatly change people's views of travelling distances.

Less plausible but more distant event is the creation of Interplanetary Transport System (ITS) by the American company SpaceX in order to transfer cargo and people from the Earth to Mars and colonize this planet (SpaceX, 2018). To reduce the costs and increase the effectiveness of spaceships' launching, the company developed a single system that can support a variety of mission types and withstand multiple entries to the Earth as well as Mars and Moon atmospheres. The first cargo transportation should take place in 2022 year, whereas the transportation of both cargo and crew – in 2024 year. Certainly, this event will be groundbreaking for the humankind since it will mean the beginning of the next evolution of humanity as multi-planetary species: people will gain an ability to travel through the space and choose a planet to live.

Another rather distant but still possible event is the industrial spread of 4D-printing technology which, in contrast to 3D-printing, include the fourth dimension – time that make the thing change over it (Tibbits, 2014). According to Tibbits (2014), the core constituents of this technology is the software that sets the parameters of the item, including its geometrical configuration, the machine which prints it and the intelligent materials which can be programmed. The main functions of these materials are shape memory, self-assembly, self-actuating and self-sensing (Li et al., 2017). The first two functions are already established and widely applied to robotic industry, for example, for the creation of self-reconfiguring modular robots which is an another joker, while other two functions which allow the items to change its change and structure under external environmental stimulus (strain, temperature, crack etc.) are still at the research stage. As Li and his colleagues argue, these qualities of intelligent materials are especially useful for the constriction of "smart" vehicles and aircrafts. There is a high likelihood, therefore, that this technology "is a first glimpse into the world of evolvable materials that can respond to user needs or environmental changes" because the printed objects are no longer static, but programmably active (Tibbits, 2014).

The idea of home-based manufacturing with the help of miniature "microfactories" instead of large-scale production is not new and being discussed from the end of the previous century (Kawahara et al., 1997). This idea seems being reasonable since the miniaturization of the production process saves energy, resources and space. At the same time this process requires highly automatic machine tools, assembly devices, transport and waste elimination systems (Kussul et al., 2002). Consequently, the construction of such a desk-top factory could be too expensive for an individual (Kawahara et al., 1997). However, modern advanced technologies can address that problem: 3D-printing machines which can become affordable for all people in

5-10 years can replace all these tools and allow people to produce small things, for example, portative electronics, at their homes. Thus, a new era of manufacturing might begin.

The neo-Luddism social movement is also not new because the first Luddites appeared in the 19th century in the UK and neo-Luddites – in 20th century. The central principal of this movement is the dismantling of following disruptive technologies: nuclear, chemical, genetic engineering, electromagnetic and computer technologies along with television which cause stress, diseases and deaths (Glendinning, 1990). Nevertheless, most of contemporary breakthroughs are done with the use of these technologies, computer ones in particular. Hence the strengthening of this resistance might become a wild card with an international impact and slowly dead end.

Summing up this part of the paper, it can be argued that the results of the study include systematized knowledge about wild cards, especially their definitions, main features and classifications that sometimes contradict to the basics of the concept. Moreover, this study contains a brief description of several national foresight projects which involve wild cards identification and methods that are used for it. Among these projects special attention was paid to Russian S&T Foresight 2030: the methodological toolkit of this project is being regularly updated and one of the recent innovations is the Radar for wild cards detection which allows conducting an in-depth analysis of possible opportunities and threats for Russian economics and S&T sector. The example of Radar's application to different S&T areas and a machine building industry was also provided.

5. Conclusion

To sum up, several conclusions of our study can be drawn. Answering the first research question, it should be pointed out that the most distinguishing features of wild cards are the surprising character and great impact of their occurrence. Consequently, not all classifications suggested by the scholars earlier correspond to these features. For example, the events with high probability or long time of occurrence can hardly be described as wild cards as well as the events with a dead end or personal impact. However, in accordance with the results of this study, the classification of wild cards can be expanded by adding 7 S&T areas to it or using different industries which might be affected by these events as a criterion of difference. As it was shown in the previous part of the paper, such an approach can contribute significantly to the analysis of wild cards and present a full picture of their emergence.

Answer for the second research question, in turn, was obtained during the analysis of various national foresight projects. Despite being initiated in different countries and for different purposes, most of these projects are aimed at the continuous monitoring of the organizational environment so as to maintain the readiness of private and public entities for radical changes of paradigm. Thus, the main role of the analysis of wild cards in national foresight projects is to detect future shocks and help to prevent or minimize negative consequences for the organization or maximize positive ones. Also, it is worth mentioning, that this kind of analysis is usually conducted to complement other types of forward-looking activities (horizon scanning, scenario planning, brainstorming, futures workshops etc.) and tightly interrelated with them. The key contribution of this analysis is a more creative approach which requires vivid imagination as well as high expertise.

Regarding the third research questions, it was approved that the most effective methodological toolkit for wild cards detection and their incorporation into national foresight projects should contain a balanced combination of quantitative and qualitative foresight methods. Such quantitative methods as bibliometrics and patent analysis, text-mining, modelling and clustering can help to identify statistical changes in areas of research which may be unnoticed by people and play the role of weak signals, while qualitative methods (backcasting, brainstorming, panels, interviews, essays, surveys etc.) can help to confirm or reject some of them using people's expertise. On the basis of combination of these methods, a number of wild cards for Russian S&T Foresight 2030 were detected and visualized on the Radar. Moreover, all the events were classified by the S&T area or economic sector of their occurrence since the scientific, technological and economic development are of paramount importance for Russia.

Suggested methodology could be employed also for developed economies, e.g. for strategies' development at national, regional, industry and corporate levels, roadmapping and scenario building processes. However it requires adjustment of its methodological toolkit to country's specificity, including economic, socio-cultural, technological and political issues. And that represents the field for further research.

References

AeroMobil (2018). Official web site. Official web site. [Electronic Resource] URL: https://www.aeromobil.com/ (date of access: 26.04.2018)

Andersen, A. D., & Andersen, P. D. (2014). Innovation system foresight. Technological Forecasting and Social Change, 88, 276-286.

Ansoff, H.I. (1984). Implanting Strategic Management, Prentice-Hall International, London.

Aven, T. (2015). Implications of black swans to the foundations and practice of risk assessment and management. *Reliability Engineering & System Safety*, *134*, 83-91.

Barber, M. (2006). Wildcards–Signals from a future near you. *Journal of Futures Studies*, *11*(1), 75-94.

Chong, T. K., Hann, J. K. Y., Hua, T. T., Fah, W. R., Lim, S. A., Seng, S. S. (2011) Risk Assessment and Horizon Scanning Experimentation Centre. [Electronic Resource] URL: https://www.dsta.gov.sg/docs/default-source/dsta-about/risk-assessment-and-horizon-scanning-experimentation-centre.pdf?sfvrsn=2 (date of access: 26.04.2018)

Coffman, B. (2011). Weak Signal Research. Journal of Transition Management. MG Taylor Corporation.

Cooper, A., Kravcik, M., Pawlowski, J., Pirkkalainen, H., Unterfrauner, E., Voigt, C. (2011). Report on Weak Signals Collection, European Commission Seventh Framework Project.

Dahrendorf Forum (2018). Official web site. [Electronic Resource] URL: http://www.dahrendorf-forum.eu/ (date of access: 26.04.2018)

Delaney, K., & Osborne, L. (2013). Public sector horizon scanning-stocktake of the Australasian joint agencies scanning network. Journal of Futures Studies, 17(4), 55-70.

European Strategy and Policy Analysis System (2018). Official web site. [Electronic Resource] URL: https://espas.secure.europarl.europa.eu/orbis/espas/ (date of access: 26.04.2018)

Gershman, M., Bredikhin, S., & Vishnevskiy, K. (2016). The role of corporate foresight and technology roadmapping in companies' innovation development: The case of Russian state-owned enterprises. Technological Forecasting and Social Change, 110, 187-195.

Glendinning, C. (1990). Notes toward a neo-Luddite manifesto. Utne Reader, 38(1), 50-3.

Gokhberg, L. M. (2013). S&T Long-Term Foresight of the Development of Russian Federation (2013) [Electronic Resource] URL: http://static.government.ru/media/files/41d4b737638b91da2184.pdf (date of access: 26.04.2018)

GOV.UK (2018). Official web site. [Electronic Resource] URL: https://www.gov.uk/government/collections/horizon-scanning-research-papers (date of access: 26.04.2018)

Grigoraș, R. (2018). Modern methods to increase resilience in security. International conference RCIC'18, Bucharest.

Hauptman, A., Hoppe, M., & Raban, Y. (2015). Wild cards in transport. European Journal of Futures Research, 3(1), 7.

Heinonen, S., Karjalainen, J., Ruotsalainen, J., & Steinmüller, K. (2017). Surprise as the new normal–implications for energy security. European Journal of Futures Research, 5(1), 12.

Hiltunen, E. (2006). Was it a wild card or just our blindness to gradual change? Journal of Future Studies, 11 (2), 61-74.

Holopainen, M., & Toivonen, M. (2012). Weak signals: Ansoff today. *Futures*, *44*(3), 198-205.

Jackson, M. (2013) *Practical Foresight Guide*. Shaping Tomorrow. [Electronic Resource] URL: https://www.shapingtomorrow.com/media-centre/pf-ch03.pdf (date of access: 26.04.2018)

Jemala, M. (2010). Evolution of foresight in the global historical context. Foresight, 12(4), 65-81.

Kamppinen, M.,O.Kuusi, and S. Söderlund. (2002). Tulevaisuudentutkimus, Perusteet ja sovellukset (in Finnish). Helsinki: Suomalaisen Kirjallisuuden Seura.

Kawahara, N., Suto, T., Hirano, T., Ishikawa, Y., Kitahara, T., Ooyama, N., & Ataka, T. (1997). Microfactories; new applications of micromachine technology to the manufacture of small products. Microsystem Technologies, 3(2), 37-41.

Kindras, A., Meissner, D., & Vishnevskiy, K. (2014). Regional foresight for bridging national science, technology, and innovation with company innovation: experiences from Russia. Journal of the Knowledge Economy, 1-22.

Kussul, E., Baidyk, T., Ruiz-Huerta, L., Caballero-Ruiz, A., Velasco, G., & Kasatkina, L. (2002). Development of micromachine tool prototypes for microfactories. Journal of Micromechanics and Microengineering, 12(6), 795.

Li, X., Shang, J., & Wang, Z. (2017). Intelligent materials: a review of applications in 4D printing. Assembly Automation, 37(2), 170-185.

Magruk, A. (2018). Weak signals in logistics in the context of the uncertainty phenomenon. *LogForum, 14*(3).

Mendonça, S., e Cunha, M. P., Kaivo-Oja, J., & Ruff, F. (2004). Wild cards, weak signals and organisational improvisation. *Futures*, *36*(2), 201-218.

Meristö, T. (1991) Scenario building in the management of companies (in Finnish), Finnish Society for Future Studies, Acta Futura Fennica VAPK-Kustannus. Valtion painatuskeskus, Helsinki.

Miles, I., Saritas, O., & Sokolov, A. (2017). Foresight for Science, Technology and Innovation.

Milshina, Y., & Vishnevskiy, K. (2018). Potentials of collaborative foresight for SMEs. Technology Analysis & Strategic Management, 30(6), 701-717.

Moro, A., Boelman, E., Joanny, G., & Garcia, J. L. (2018). A bibliometric-based technique to identify emerging photovoltaic technologies in a comparative assessment with expert review. *Renewable Energy*, *123*, 407-416.

Office of the Director of National Intelligence (2018). Official web site. [Electronic Resource] URL: https://www.dni.gov/index.php (date of access: 26.04.2018)

Park, C., & Cho, S. (2017). Future sign detection in smart grids through text mining. *Energy Procedia*, *128*, 79-85.

Petersen, J. L. (1997). *Out of the blue: wild cards and other big future surprises: how to anticipate and respond to profound change*. Danielle LaPorte Book.

Ponomareva, J. V., & Sokolova, A. (2015). The identification of weak signals and wild cards in foresight methodology: Stages and methods.

Popper, R. (2012). Mapping futures studies. Foresight-Russia, 6(2), 56-75.

Qi, Y., & Tapio, P. (2018). Weak Signals and Wild Cards Leading to Transformative Disruption: A Consumer Delphi Study on the Future of e-Commerce in China. *World Futures Review*, *10*(1), 54-82.

van Rij, V. (2013). New emerging issues and wild cards as future shakers and shapers. In Recent Developments in Foresight Methodologies (pp. 67-89). Springer, Boston, MA.

Rijkens-Klomp, N., & Van Der Duin, P. (2014). Evaluating local and national public foresight studies from a user perspective. Futures, 59, 18-26.

Rockfellow, J. D. (1994). Wild cards: Preparing for'the big one'. *The Futurist*, *28*(1), 14.

Saritas, O., & Proskuryakova, L. N. (2017). Water resources–an analysis of trends, weak signals and wild cards with implications for Russia. *foresight*, *19*(2), 152-173.

Saritas, O., & Burmaoglu, S. (2015). The evolution of the use of Foresight methods: a scientometric analysis of global FTA research output. Scientometrics, 105(1), 497-508.

Saritas, O., & Smith, J. E. (2011). The big picture–trends, drivers, wild cards, discontinuities and weak signals. *Futures*, *43*(3), 292-312.

Saul, P. (2006). Seeing the future in weak signals. Journal of Futures Studies, 10 (3), 93-102.

SETI Institute (2018). Official web site. [Electronic Resource] URL: https://www.seti.org/ (date of access: 26.04.2018)

Smith, C. J., & Dubois, A. (2010). The 'wild cards' of European futures: planning for discontinuities? *Futures*, *42*(8), 846-855.

Sokolov, A., & Chulok, A. (2016). Priorities for future innovation: Russian S&T Foresight 2030. Futures, 80, 17-32.

Sokolov, A., Chulok, A., & Mesropyan, V. (2013). Long-term science and technology policy–Russian priorities for 2030.

SpaceX (2018). Official web site. [Electronic Resource] URL: http://www.spacex.com/ (date of access: 26.04.2018)

De Spiegeleire, S., van Duijne, F., & Chivot, E. (2016). Towards Foresight 3.0: The HCSS Metafore Approach—A Multilingual Approach for Exploring Global Foresights. In Anticipating Future Innovation Pathways Through Large Data Analysis (pp. 99-117). Springer, Cham.

Steinmüller, K. (2017). The World in 2040. Framework Conditions for New Kinds of Terrorism. *Identification of Potential Terrorists and Adversary Planning: Emerging Technologies and New Counter-Terror Strategies*, *132*, 25.

Steinmüller, K. (2003). The future as Wild Card. *A short introduction to a new concept*.

Takala, A., & Heino, O. (2017). Weak signals and wild cards in water and sanitation services–exploring an approach for water utilities. *European Journal of Futures Research*, *5*(1), 4.

The Australasian Joint Agencies Scanning Network (2018). Official web site. [Electronic Resource] URL: https://www.ajasn.com.au/ (date of access: 26.04.2018)

The Guardian (2018). Avoid Gulf stream disruption at all costs, scientists warn. [Electronic Resource] URL: https://www.theguardian.com/environment/2018/apr/13/avoid-at-all-costs-gulf-streams-record-weakening-prompts-warnings-global-warming (date of access: 26.04.2018)

Tibbits, S. (2014). 4D printing: multi-material shape change. Architectural Design, 84(1), 116-121.

Tzezana, R. (2017). High-probability and wild-card scenarios for future crimes and terror attacks using the Internet of Things. *foresight*, *19*(1), 1-14.

Vishnevskiy, K., & Yaroslavtsev, A. (2017). Russian S&T Foresight 2030: case of nanotechnologies and new materials. *foresight*, *19*(2), 198-217.

Williams, H. (2012) Horizon Scanning – A Comparative Analysis. Report to European Forum of Forward Looking Activities. [Electronic Resource] URL: http://www.samiconsulting.co.uk/training/documents/Horizon%20Scanning1.pdf (date of access: 26.04.2018)

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