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INNOVATIVE CLASSIFICATION OF TECHNOLOGY FORESIGHT METHODS

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Abstract. Since the end of the twentieth century there is a noticeable worldwide paradigm shift in future studies which are so far based mainly on statistical methods. The development of a social, not only a strictly scientific vision of the future has become crucial. It appears that the biggest role in this context played technology foresight programs (whose origins go back even to the 70's), integrating traditional methods of forecasting as well as those derived from the social sciences, economics, management science, etc. The paper presents a rich collection of foresight methods identified by the author, a general outline and characteristics of various types of methods, and an innovative classification of technology foresight research methods. Because of the huge complexity of the approach to technological foresight and its further evolution, the ability to classify and identify the typology of methods may be necessary for an orderly and rational way of structuring foresight projects.

Keywords: technology foresight, research methodology, cluster analysis, classification, typology.

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1. Introduction

The complexity of social, technological, political and economic phenomena makes their anticipation necessary. The determinants of units' functioning, indispensable for choosing a working strategy and for competing should be created and reconstructed in advance (Pawłowski, K., Pawłowski, E. 2005; Skawińska 2007).

Traditional planning, modeling or forecasting of technological development should be strengthened by skills to use modern organizational approaches in the future management field. One of more important tools in this range is *technology foresight* programs, which integrate varied approaches: predictive, statistical, economic, technological, connected with management, etc. and which relate equally to the development of technology and economy, science and politics, social conditions and cultural aspects (Unido… 2005; Okoń-Hordyńska 2006).

The article defines the concept of technology foresight and characterizes the factors affecting its research process identified by the author on the basis of both literature review as well as direct observation (author has so far actively participated in five foresight initiatives). The author has identified an extensive list of research methods which can be used in technology foresight projects. Considering that to date many foresight methods belong to several types, the author attempted to create his own, innovative classification, based on the cluster analysis, portraying groups of methods be characterized by similar features. In the opinion of the author these results can considerably facilitate the selection of individual methods in the procedure of building the foresight research process.

2. Essence of technology foresight

One of most popular definitions of foresight, was the one proposed in 1983 by Ben Martin and John Irvine (Martin 2010): *Foresight is the process involved in systematically attempting to look into the long-term future of science, technology, economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefits.*

Technology foresight is both the process and the tool, with the help of which the consensus of scholars, engineers, representatives of industry, workers of public administration as well as wide society is obtained.

D. Stout identified three following fundamental principles of foresight as a process (Stout 1995): (1) foresight is not foreseeing future, but creating it; (2) neither a single man, nor a single company it is able to create future alone; (3) new knowledge can benefit many, knowledge kept secret is worthless knowledge.

Foresight can be defined as a process of systematic inquiry into the future, the results of which affect the dynamic adjustment of the far-reaching options of the future to changing environments (Reger 2001). Foresight consists in understanding the future using the fundamental laws and factors of the observed structures and phenomena (Reid, Zyglidopoulos 2004).

In research of the future of complex issues a single scientific method will never be sufficient to achieve the aim of the research. The quality of the results of foresight research will depend on the skilful use of a set of methods which expand the possibility of anticipating the future. Methods used individually or in inappropriate combination reduce the optimum ability of identifying the future of possible technologies, therefore it is justifiable to search for a best combination of chosen methods. This can turn out the most essential working with enlarging the efficiency of foresight process (Slaughter 1998).

3. Factors influencing the technology foresight research process

A factor is one of causes producing the result (Polish Language Dictionary). For the design process, and the correct choice of suitable research methods, to be an effective process, indispensable are identification, profiling and indication of all factors influencing the technology foresight research process (Slaughter 2004).

On the basis of past studies the author has completed identification of factors which influence the technology foresight research process (Table 1).

Table 1. Factors influencing the technology foresight research process

Category	Factors
Institutions realizing foresight	public institutions; government; the academies of sciences; industrial associations; firms
Range of area studied	individual technology; individual discipline; wide fields; whole areas of science and technique
Aims, tasks, the functions of foresight	determination economic priorities; building social consensus over some issues; delimitation strategic economic directions
Levels	supranational; subnational; national; regional and local level; business
Meaning	foresight as a product – foresight as a process; formal – informal
Orientation	orientation on need; orientation on problem; orientation on use
Approach to object of investigations	professional analytical model; model of social changes
Aspects	technological; strategic; social; cultural; political; economic; scientific; consumer; etc.
Kind of possessed data	quantitative; qualitative; in digital form; in printed form
Data source	literature; experts; own research, universities; press; medias; scientific publications
Kind of stakeholders	scientists; businessman; politicians; society
Work environment	scientific-business; virtual-real
Time	horizon; project period
Objectives	policy development; networking, shared visions, public discussion, future thinking
Budget of project	high; low
Access to the data	quantitative – qualitative; low – wide
Legitimacy of a combination of methods	low – medium – high – very high

References: The authors' study based on Magruk 2005; Okoń-Hordyńska 2006; Popper *et al.* 2006.

Above mentioned factors and their proper selection are essential in the technology foresight research process. The author's own research shows that not taking all these factors into account foresight becomes a process which is non-systematic and incoherent, and is based solely on intuition and sometimes the inexperience and irresponsibility of practitioners and organizers.

4. Methods of technology foresight

As a result of the existence of foresight for some time such thing as research: basis (perspectives), paradigms and methods have been well developed. The interdisciplinary character of foresight causes that it uses many research methods. A method is a conscious and practical course of action leading to the achievement of an intended aim (Polish Language Dictionary).

One of the characteristics of foresight is the free selection of research methods used within the process. At present the list of methods and techniques which can be used is very extensive (Table 2) and still open.

There are important conditions when selecting appropriate methods. Literature highlights the three most important, and theese have been fulfilled by the author of this article (Alexandrova *et al.* 2007): (1) a most complete list of methods which can be used in foresight studies, including both popular methods as well as those less frequently used, (2) knowledge about the characteristics of each method, i.e., understanding the key features of each one (3) establishing a set of criteria that will allow the selection of appropriate methods and the rejection of other techniques.

Under the concept of MCDM lies a wide range of Multiple Criteria Decision Making Methods such as (Zavadskas, Turskis 2011; Gass 2005; Kildienė *et al.* 2011) MAUT, UTA, COPRAS, SAW, TOPSIS, Electre, Vikor, Promethee, Moora. The creators of the various techniques are, respectively, Keeney, R. L.; Jacquet-Lagrèze, E. and Siskos, J.; Zavadskas, E. K.; Kaklauskas, A.; MacCrimon, K. R.; Hwang, C. L. and Yoon, K.S.; Roy, B.; Opricovic, S.; Brans, J. P.; Brauers, W. K. Other multicriteria methods such as AHP (developer: Saaty, T. L.), DEA, PRIME, SMART, prioritization, were extracted separately because of potential foresight research applications (Salo *et al.* 2003; Amanatidou 2008; Lee, H., Lee, Ch. 2008).

Despite such a wide range of conditions of foresight research, experts taking part in the realization of these types of programs agree with the opinion that a universal methodology of conducting them does not exist. On the one hand this situation is beneficial because those carrying out such programs are not hampered by strict guidelines. Meanwhile, on the other hand, lack of methodology conditioned by the above-mentioned factors can cause many difficulties since it is not known whether the chosen methods and techniques are optimal in the given situation.

5. Typology of technology foresight methods

The considerable freedom of choice in the selection of methods consisting the investigative apparatus of a foresight program (the project) decides about its elasticity as well as – when the choice made is accurate – the effectiveness of foresight as a predictive tool. Simultaneously the necessity of designing the course of the research process, depending on the needs and restricting conditions, can become a hindrance and forces the search of areas in range of which the systematization of accessible methods is possible, which facilitates synergistic composition of investigative methodology in a holistic framework.

In this chapter an attempt at typology of a set of methods characteristic to technology foresight has been made. According to the author this process can become the starting point

Table 2. Methods and techniques possible to use in technology foresight programs

Action Learning/Analysis	Environmental Scanning	Morphological Analysis	STEEPV Analysis
Agent Modeling	Essays	Multiple Perspectives Assessment	Stochastic Forecasting
AHP	Expert Panels	Object Stimulation	Structural Analysis
Alternative History	Factor Analysis	Patent Analysis	Survey
Analogies	Failure Mode & Effects An. (FMEA)	Polling	Sustainability Analysis
ANKOT	Force Field Analysis	PRIME	SWOT Analysis
Assumption Reversal	Future History	Prioritization	Synectics
Backcasting	Future Mapping	Probability Trees	System Dynamics
Back-View Mirror Analysis	Futures Biographies	Relevance Trees	Technolgy Watch
Benchmarking	Futures Wheel	Requirement Analysis	Technological Scanning
Bibliometrics	Genius Forecasting	Retrospective Analysis	Technological Substitution
Brainstorming	Incasting	Rich Pictures	Technology Assessment
Business Wargaming	Indicators/ (Time Series Analysis)	Risk Analysis	Technology Barometer
Causal Layered Analysis	Input-Output Analysis	Role play (Acting)	Technology Mapping
Citizen Panels	Institutional Analysis	RPM (Robust Portfolio Modeling)	Technology Positioning
Classification Trees	Interviews	Scenarios	Technology Roadmapping
Cluster Analysis	Issues Management	Science Fiction Analysis	Technology Scouting
Coates and Jarratt	Key Technologies	Scientometrics	Theory of Constraints
Conferences/Workshops	Lateral Thinking	S-Curve Analysis	Trend Extrapolation
Content Analysis	Literature Review	Sensitivity Analysis	Trend Impact Analysis
Correspondence Analysis	Long Wave Analysis	Shift-Share Analysis	Trial and Error
Cost-Benefit Analysis	Macrohistory	SMART	TRIZ
Critical Influence Analysis	MANOA	Social Impact Assessment	Visualization
Cross-Impact Analysis	MCDM	Social Networks Analysis	Voting
DEA	Megatrend Analysis	Source Data Analysis	Weak Signals
DEGEST	Metaphors	Speculative Writing	Web Research
Delphi	Migration Analysis	SRI Matrix	Wild Cards
Desk Research	Mindmapping	Stakeholder Analysis/MACTOR	Webometrics
Divergence Mapping	Modeling and Simulation	State Of the Future Index (SOFI)	Word Diamond

References: Authors' study based on Armstrong, J. and Armstrong, S. 2006; Cachia *et al.* 2007; Chamon *et al.* 2007; Jasiński 2007; Könnölä *et al.* 2007; Popper *et al.* 2007; Popper and Korte 2004; Rohrbeck 2007; Santos and Fellows 2007; Schwarz 2007; Shirai 2007; Technology Foresight… 2003; Technology Futures… 2004; Tran and Daim 2008.

to effective combining of individual methods into research methodologies structuring specific foresight undertakings.

Table 3 presents types of methods according to the following criteria: thinking about the future, type of data, method of data acquisition, kind of co-operation, working environment, reference to time, source of data, reference to technology, orientation, meaning for foresight, stage of research, character of results, essence of research, way of thinking, layer and way of inference. In the author's opinion the following profile can be helpful, on one side for novice foresight practitioners, and on the other, however, for experts dealing with technology foresight investigative methodology in a professional way as well as in the optimization process.

Table 3. Typology of technology foresight research methods

Criterion	Types of methods
thinking about the future	explorative (foreseeing) – based on uncertainty (managing) – normative (creating)
type of data	quantitative – indirect – qualitative
method of data acquisition	heuristic – analytic
kind of cooperation	bottom-up – top-down
working environment	based on virtual environment – based on real environment
reference to time	shaping future – analyzing present state – based on the past
source of data	using original data – using secondary data
referencel to technology	describing factors which influence technology development – determining influence of technology development for other aspects of life
orientation	focused on product – focused on process
meaning for foresight	formal – alternatively
stage of research	preliminary – recruitment – generation – action – final – renewal
character of results	textual – graphical – verbal
essence of research	based on creativity – interaction – evidence – expertise
way of thinking	evolutionary – revolutionary
layer	mathematical – social – engineering – system
way of inference	inductive – deductive

References: The authors' study based on Aaltonen and Sanders 2006; Bishop *et al.* 2007; Blueprints… 2007; Cachia *et al.* 2007; Chrisidu-Budnik *et al.* 2005; Dolby 1998; Gašparíková 2007; Coates *et al.* 2010; Grupp and Linstone 1999; Havas 2008; Jakuszewicz *et al.* 2006; Könnölä *et al.* 2007; May 2009; Popper 2008a, 2009; Tran and Daim 2008; Voros 2006.

In explorative methods the present, from which follows the anticipation of a possible or probable future is the initial point. In case of normative methods, the activity of explorers is directed in the opposite direction. At the beginning a desirable vision is presented (created). Based on this the researchers define what should be done to reach such a state or to avoid it (Lüdeke 2007). Methods based on uncertainty are those which accept unpredictability and are focused on management of critical and strategic changes, often based on tsunamis of change (May 2009).

During creating of the future, and especially in technology foresight programs, maintenance of the equilibrium in the use quantitative and qualitative methods is advisable.

Qualitative methods are based on expert opinions (presumptions), while in quantitative methods numerical parameters characterizing the studied phenomenon or the object of investigation are defined. Qualitative methods should be used with very complex phenomena, trends which are difficult to numerically visualize unambiguously. Quantitative methods are mainly based on numerical representation of simple phenomena using mathematical models for this purpose. It is possible to distinguish so called indirect methods. With their help complex phenomenon can be represented using numerical data (Unido… 2005; Gašparíková 2007).

The next set of methods, emphasized on account of the manner of data acquisition, are the heuristic methods – based on experts opinion (intuition), and analytic methods – based on accessible knowledge, evidence, statistics, etc. (Popper, Korte 2004).

Particularly important in foresight research is the distinction between bottom-up and top-down methods. Foresight practitioners often underline the validity of bottom-up research based on open participation of the widest group of stakeholders from different environments. In case of top-down research the main (and often the only) role is played by the experts (Popper, Korte 2004).

Making work environment into a criterion, technology foresight methods can be divided into two groups: those which use digital tools (computer programs, internet, etc.), and those which do not require the use of IT infrastructure (Popper, Korte 2004).

Foresight methods do not study only the future of a given phenomenon. Often, in order to define the desirable vision it is indispensable to reference the present or a past situation.

With the criterion of the source of data, methods using original data (gathered with interviews, for example) as well as method using secondary data (demographic data, epidemiological, etc.) are distinguished (Technology… 2004).

The next type of methods, particularly useful in technology foresight, consists of methods in which technological aspect plays the leading role. In this group it is possible to distinguish methods describing factors which influence technology development and methods determining the influence of technology development on other aspects of life.

On account of orientation it is possible to single out methods focused on the product, as well as method focused on the process. Taking into consideration the character of foresight projects, methods from second group are more important in the hierarchy. Foresight should be a continuous process, having an iterative character, as it takes place, for example, in Japan.

Conducting of foresight projects on wider scale since the 80's allows for distinguishing of formal methods – checked and applied in many projects, as well as optional methods – practiced less often (Popper *et al.* 2007).

An important type of methods, especially for novice foresight practitioners, can become type distinguished on account of the stage of research. Here, it is possible to distinguish 6 kinds of methods. The first group is the preliminary methods. The second group is the recruitment methods. With the help of these methods key shareholders of the foresight process are mobilized and engaged. The third group – the Generation methods are responsible for generating new knowledge through exploration, analysis and anticipation of the possible future. The fourth group of methods is action methods, shaping the future through strategic planning. The next to last group of methods in this category is final methods, identifying the final priorities of the research and development of technology. Considering the specifics of foresight projects it is possible to identify the last group in this category – the renewal methods, responsible for next iterations of the program (Popper *et al.* 2008b).

Considering the essence of the research (based on the so-called "foresight diamond") it is possible to distinguish methods which are based on: creativity, interaction, evidence, expertise. It would be unadvisable for well-chosen research methods to be dominated by one of the dimensions mentioned. Expertise links future possibilities with present scientific and technological challenges. Creativity often is an extreme image of the future. Cooperation facilitates the creation of one common (to all participants) vision of the future. Evidence is a good, real starting point for further research (Popper *et al.* 2007).

Considering the wide scale of technology foresight methods which can be used, the author has distinguished one more group of methods – based on the character of the results. In this type textual methods, graphical methods and verbal methods are distinguished.

Among perspective methods J. Voros distinguishes two types of methods: evolutionary methods and revolutionary methods. In the first group of methods the starting point is the present, which is followed by evolutionary, relatively stable, predictable and reliable development. These methods are distinguished by the following attributes: the evolution of extrapolation, regularity, smoothness, continuity, gradual growth. Revolutionary methods which focus on a distant, hard to foresee,, based on sudden events, future (most often possible and desirable), which is not necessarily connected with the present, are often characterized by a sudden, a distinct point of view. Methods from this group can be said to have the following attributes: revolution, break, separation, disruption, twist, sudden spike (Voros 2006).

In accordance to the criterion of the layer a mathematical method can be distinguished, which emphasizes the social aspect with an engineering approach and systemic methods. The methods of the last two groups have been applied for a long time and are strongly grounded in strategic management. Mathematical methods and those which emphasize the social aspect are not very common in future studies. Engineering methods relate to the future as a certain kind of a continuation of the present. Mathematical methods, in turn, are often based on complex adaptive systems. Systemic methods help to clarify many uncertainties (Aaltonen, Sanders 2006).

Inductive and deductive methods are distinguished on the basis of the way of infering . Inductive methods, developed mainly in experimental studies, also called methods from the particular to the general, are based on the formulation of claims on the basis of individual conditions of single repeatable observations. Deductive methods rely on the derivation of logical conclusions based on the opinions and recognized opinions and laws, from general to particular (Cempel 2002).

6. Cluster analysis of technology foresight methods

Since many foresight methods belong to several types the author attempted to develop his own classification, creating groups of methods characterized by similar features. This operation may be a significant contribution to the process of singling out groups of substitutive and complementary methods. This process can also considerably facilitate the selection of individual methods in the building of the foresight research process. Among other things, supported by the data from Tables 1 and 3, a list of features characterizing research methods was created. In the author's studies one of more popular taxonomy method – numerical taxonomy was used. Numerical taxonomy methods can be applied everywhere where it is possible to apply statistical methods i.e. in biology, medicine, sociology, economy. The notion of numerical taxonomy originates from biology sciences and was introduced by Caina and Harrisona, as a way of the calculation similarity between organisms based on all available features, without any preliminary valuation (Rutkowski 2000). In traditional English literature classic notions: "taxonomy", "numerical taxonomy" are used. In turn the term "cluster analysis" is universally used in American literature (Pociecha *et al.* 1988).

Cluster analysis consists of four basic stages (Sagan 2000):

1. Selection of variables and method of determining similarities between objects.
2. Selection of a method of subordinating objects into homogeneous groups.
3. Choice of number of clusters identified.
4. Interpretation and dividing of clusters obtained.

A binary system of coding the attributes was applied because it is unambiguous as well as the one most often used in numerical taxonomy. In an investigation the first stage is very important. Sixty five variables were chosen, which in the author's opinion correctly describe the objects assembled (research methods) and accurately refer to the goals of the analysis. These variables are:

1. Explorativity; 2. Rely on Uncertainty; 3. Normativity; 4. Qualitative character; 5. Indirect nature; 6. Qualitative Character; 7. Heuristic Character; 8. Analyticity; 9. Bottom-up Character; 10. Top-down Character; 11. Rely on Working in a Virtual Environment; 12. Rely on Working in the Real Environment; 13. Shaping the Future; 14. Analysing Present State; 15. Appeals to the Past; 16. Describing Factors Which Influence Technology Development; 17. Determining Influence of Technology Development for Other Aspects of Life; 18. Focus on the Product; 19. Focus on Process; 20. Formal Nature; 21. Optional Nature; 22. Preliminary Character; 23. Recruitment Character; 24. Refresher Character; 25. Graphic Character; 26. Text Character; 27. Verbal Nature; 28. Unambiguity (exclusion the free choice of usage of different ways and principles); 29. Expensive Character; 30. Requiring the Participation of a Numerous of Human Resources; 31. Time-consuming; 32. Objectivity; 33. Regularity; 34. Penetrative Character; 35. Rely on Creativity; 36. Rely on the Interaction; 37. Rely on Evidence; 38. Rely on Expertise; 39. Susceptibility; 40. Resistance to External Factors; 41. Resistance to Internal Factors; 42. Scanning Character; 43. Forecasting Character; 44. Creating Vision; 45. Planning Character; 46. Action Character; 47. Evolutionary Character; 48. Revolutionary Character; 49. Understanding Character; 50. Concerning Synthesis and Modeling; 51. Concerning the Analysis and Selection; 52. Mathematical Perspective; 53 Social Perspective; 54. Engineering Approach; 55. Systemic Thinking; 56. Technological Perspective; 57. Cognitive Perspective; 58. Inductive Character; 59. Deductive Character; 60. Reliance on Statistical Inference; 61. Using the Raw Data; 62. Using Secondary Data; 63. Generating Codified Results; 64. Complex Attitude; 65. Shot Scenario.

When it comes to the way of subordinating objects to homogeneous groups, the hierarchic approach was chosen. To create hierarchic diagrams the author used a module for cluster analysis of the STATISTICA 9 software. Cluster analysis is the typical method practiced in taxonometrics. When using two-stage features three types of distance are most often chosen: euclidean, squared euclidean and the city-block. In the present study research methods were divided into more homogeneous groups, using an agglomerate taxonomy method. The Ward's method (recognized as very effective in creating homogeneous clusters (Grabiński, Sokołowski 1984) was chosen, which is part of a group of procedures developed by G. M. Lance, W. T. Williams and J. H. Ward. This method attempts to minimize the sum of squares of any two clusters that can be formed at each step. This method is regarded as very efficient; however, it tends to create clusters of a small size (Nowak 1980). Distances between research methods were measured by using the city-block distance – "Manhattan". In the case of measuring the distance "Manhattan" and a binary system of coding the attributes, the distance between the two clusters presents the number of features by which one cluster differs from the other (Rutkowski 2000).

The results of the agglomerate taxonomy method are presented as a tree of connections (a diagram) in figure 1. Depending on the distance examined between objects it is possible to distinguish 10 homogeneous clusters of research methods.

Each class received an original name which characterizes their general nature (in terms of a combination of their features): I. Consultative; II. Creative; III. Prescriptive; IV. Multicriterial; V. Radar; VI. Simulation; VII. Diagnostic; VIII. Analytical; IX. Survey; X. Strategic. Table 4 presents a group of methods belonging to a particular class. These methods are listed in order of appearance in the diagram.

First class is a group of consultative methods, or those which involve the collection and analysis of opinions (usually expressed verbally) of the broadest range of stakeholders who are not necessarily experts in a given field. A method of this class may be a useful tool in every phase of foresight studies, with particular regard to the initial and final stages. Results of consultative methods are a strong indicator of a trend in the area investigated. One of the main advantages of these methods is their transparency and accessibility.

Second class brings together creative methods and those which in systematic way analyze, study, draft a vision of reality, while specifically relating to the consequences of this fact, e.g., economic, political, environmental, and descriptive roles potential stakeholders should play. These methods are characterized by the greatest, among all the classes, freedom, flexibility and spontaneity in understanding the examined phenomena. Most of the methods do not have strictly codified, scientific procedures. This class allows the emphasis of the validity of a forward-looking aspect, while at the same time expressing the complexity and multi-perspectivity of examined objects. These classes can also be described as revolutionary, because the final result of applied research approaches often break –, prevailing stereotypes of visions, proven patterns, methods and approaches – the picture of a future reality.

Prescriptive class is the third cluster isolated in the analysis process. It is a group of methods based on creativity and on defining the vision of development closely related to the anticipation of the future, which have a more formalized form, with less flexibility than the described above, the second class of creative methods. Prescriptive methods are addressed primarily to experts in a specific field, and permit one to look at the current situation through a prism of an imaginary future.

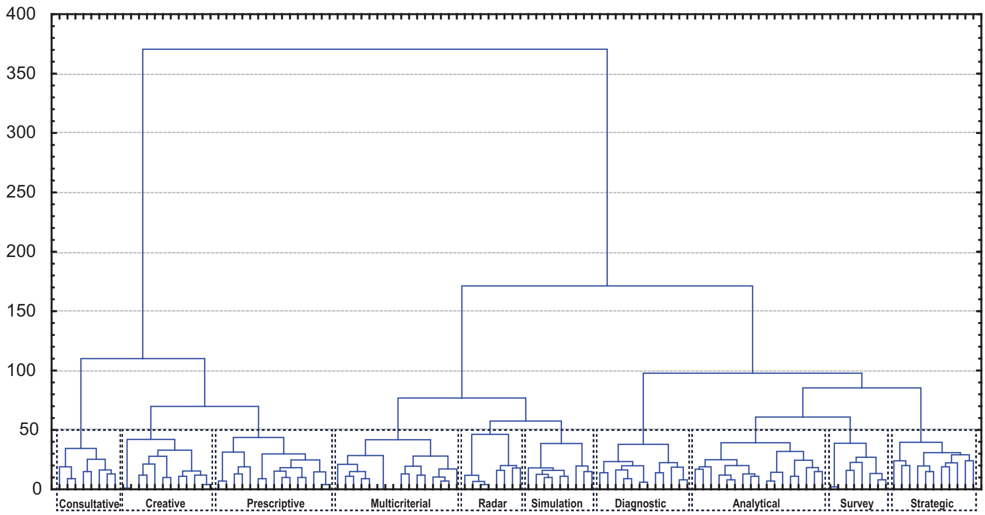

Fig. 1. Diagram of clusters of technology foresight method
References: The authors' study.

Table 4. Classification of technology foresight research methods

Innovative classes	Methods belonging to each class
Consultative	Voting, Polling, Survey, Interviews, Expert Panels, Essays, Conferences, Workshops, Citizen Panels, Brainstorming
Creative	Wild Cards, Weak Signals, Mindmapping, Lateral Thinking, Futures Wheel, Role Play, Business Wargaming, Synectics, Speculative Writing, Visualization, Metaphors, Assumption Reversal
Prescriptive	Relevance Trees, Morphological Analysis, Rich Pictures, Divergence Mapping, Coates and Jarratt, Future Mapping, Backcasting, SRI Matrix, Science Fiction Analysis, Incasting, Genius Forecasting, Futures Biographies, TRIZ, Future History, Alternative History
Multicriterial	Key Technologies, Source Data Analysis, Migration Anal., Shift-Share Anal., DEA, Factor Anal., Correspondence Anal., Cluster Anal., Sensitivity Anal., AHP, Input-Output Anal., Priorization, SMART, PRIME, MCDM
Radar	Scientometrics, Webometrics, Patent Analysis, Bibliometrics, Technological Substitution, S-Curve Anal Technology Mapping, Analogies
Simulation	Probability Trees, Trend Extrapolation, Long Wave Anal., Indicators, Stochastic Forecast, Classification Trees, Modeling and Simulation, System Dynamics, Agent Modeling
Diagnostic	Object Simulation, Force Field Anal., Word Diamond, SWOT, STEEPVL, Institutional Anal., DEGEST, Trial&Error, Requirement Anal., Theory of Constraint, Issue Management, ANKOT
Analytical	SOFI, Stakeholder Anal., Cross-Impact Anal., Trend Impact Anal., Structural Anal., Megatrend Anal., Critical Influence Anal., Tech. Barometer, Cost-Benefit Anal., Technology Scouting, Technology Watch, Sustainability Anal., Environmental Scanning, Content Analysis, FMEA, Risk Anal., Benchmarking
Survey	Web Research, Desk Research, Tech. Assessment, Social Network Anal., Literature Review, Retrospective Analysis, Macrohistory, Back-View Mirror Analysis
Strategic	Technology Roadmapping, Tech. Positioning, Delphi, Scenarios, Social Impact Assessment, RPM, Technological Scanning, Multiple Perspectives Assessment, Causal Layered Analysis, MANOA, Action Learning

References: The authors' study.

The fourth cluster is class of multicriterial methods. One of the main tasks of these methods is optimalization based on uncertainty (most often using a virtual environment) and the analysis and selection of a wide range of data concerning the current state. The methods of this group, often using expert opinion, allow the measuring of the mutual relationship between a large group of variables and criteria characterizing investigated objects.

Radar methods – the fifth group – focus on monitoring and analyzing, among others: bibliographical, Internet, and patent references, primarily related to technology as well as to other aspects, in order to detect important signals about the latest research findings, technological innovation, and any potential opportunities and threats.

The sixth, is a class of simulation methods. The most characteristic features of this cluster are: basis on work done in a virtual environment, focus on the process, high cost and time of investigation, thoroughness in the research, use of the properties of synthesis and modeling. Simulation methods allow the reflection of the behavior of a given model, which is a simplification of a selected fragment of reality. Methods facilitate the simulation and analysis of all possible variants of a complex system (e.g., economic, social) in the form of interactive links and combinations.

The seventh class consists of 12 diagnostic methods. These methods, rely on the different types of expertise, both subjective and objective, analyze, mostly in a systemic manner, identify, and assess the current status of the test object such as a region, characterizing the various factors and trends (political, legal, economic, social, technological, environmental, demographic, etc.) stimulating and inhibiting its (the object) development. The most characteristic features of this group are: time-consumption, cost, generating a codified text results, reliance on in-depth expertise, and resistance to external factors.

The eighth cluster is the most abundant cluster consisting of 17 analytical objects. Key characteristics of this group is time-consuming research methods focused on the product appeal to the objective future. The methods of this group allow (often using graphs, charts) the examination of developmental trends, of driving forces, variants of the changes, the structure of the reality being tested, of the public and potential stakeholders.

To the ninth survey class belong the so-called: diachronic and nomothetic review methods (resistant to external and internal factors) consisting of a time-consuming examination and evaluation of available evidence-based data, previous operations in the selected field of research and studies of space-time targeting the social systems.

The last, tenth, cluster is formed by strategic methods designing and analyzing complex objects. This class consists of evidence-based cognitive, insightful methods relating to the future of the object being analyzed. In the methods discussed the future image is divided into more detailed elements. The methods of this group are helpful in planning, scenario building, decision-making in solving complex decision problems and change management.

Based on cluster analysis a general conclusion can be drawn that each cluster forms a group of substitute methods relative to each other and complementary to the methods of other clusters. In such cases you should avoid the simultaneous use of all methods from one group, especially in reference to only one research context. In this case, the methods share similar information resources, and generate results in a similar manner.

The innovative classification presented in this section allowed us to find a common semantic ground of the methods belonging to a certain group which use a similar range of research. Innovative cluster division, because of the extensive foresight methodological environment, also allows to identify the characteristics of individual clusters, which should be remembered in the process of formulating a foresight research methodology, in a clearer way. The classification performed does not of course eliminate the ability of using several methods from the same group in one study. In certain circumstances it is even desirable. Analysis indicates, however, that the use of methods from only one group can impoverish these studies, by not taking into account many essential aspects with the same intensity.

7. Conclusions

In the opinion of the author, the typology and classification introduced in the article can possibly become helpful in activity directed at effective design of foresight technology research methodologies, influencing the accurate marking of far-reaching directions of development.

A general outline of a profile of individual types, as well as classification of technology foresight research methods, was introduced in the article, which creates a background for further investigation. Considering the considerable complexity of the approach to thinking about the future such as technology foresight and its continued evolution, the author's research can turn out to be indispensable for a systematic and rationally well-founded structuralization of foresight projects.

The current division into types (Table 3) is characterized by a great flexibility in the choice of foresight methods, which on one hand, it is highlighted as an advantage of foresight, and on the other hand can create many questions, especially for the new theorists of foresight. A wide range of research methods (Table 2) and their innovative classification (Fig. 1, Table 4) allows rational modification of a combination of research methods while retaining the essential feature of foresight – flexibility in choice research methods. Innovative classification allows for the extraction of essential features of homogeneous groups of methods, and at the same time for the discovering of unknown, until now, structure of the analyzed data.

The overall choice of methods should be subordinated to research objectives. When it comes to technology foresight research issues should be considered the problem. Such authors as M. Alexandrova, D. Marinova, D. Tchonkova, M. Keenan, R. Popper, A. Havas stress that foresight research methods should always be selected after establishing the objectives and never in the other way around (Alexandrova *et al.* 2007; Popper 2008a, b). Only after the identification of the phenomena, questions and hypotheses, and the relationship between them, we may begin the process of selecting methods, research tools, indicators. Selected methods should therefore give the fullest, most accurate and reasonable answers to the investigator's questions (Nowak 2006). In case of foresight, such functions can be carried out through different methods. It is therefore important to know the methods which may complement or substitute each other. It should be remembered that the objective is not the only determinant of the choice of a method or methods of the group. Other factors which were identified by the author's article (Table 1, Table 4) are also important.

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NAUJA TECHNOLOGIJŲ PROGNOZAVIMO METODŲ KLASIFIKACIJA

A. Magruk

Santrauka. Nuo XX a. pabaigos visame pasaulyje ateities studijos daugiausia rėmėsi statistiniais metodais. Svarbi tapo socialinės raidos ne tik griežtai mokslinė ateities vizija. Didelis vaidmuo čia atiteko technologijų prognozavimo metodams (jų ištakos siekia aštuntąjį dešimtmetį), integruojantiems tradicinius prognozavimo metodus ir metodus, pasiskolintus iš socialinių, ekonomikos, vadybos ir kitų mokslų. Autorius pateikia ilgą prognozavimo metodų sąrašą, bendrus jų bruožus ir charakteristikas, taip pat siūlo novatorišką technologijų prognozavimo metodų klasifikaciją. Prognozavimo metodai tampa vis sudėtingesni, jie evoliucionuoja, todėl metodų klasifikacija ir tipologija gali praversti struktūrizuojant prognozes.

Reikšminiai žodžiai: technologijų prognozavimas, mokslinių tyrimų metodologija, klasterinė analizė, klasifikavimas, tipologija.

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