BUSINESS, MANAGEMENT AND EDUCATION
ISSN 2029-7491 / eISSN 2029-6169
2015, 13(2): 308–320
doi:10.3846/bme.2015.294

FORWARD-LOOKING PLANNING OF TECHNOLOGY DEVELOPMENT

Katarzyna HALICKA

Bialystok University of Technology, Wiejska 45A str., 15-351 Bialystok, Poland
E-mail: k.halicka@pb.edu.pl

Received 30 June 2015; accepted 4 November 2015

Abstract. The main aim of this article is to adapt the Future-Oriented Technology Analysis (FTA) to prospective planning of technology development. Firstly, the article presents the assumptions, methods and idea, as well as the concept of the FTA method. Moreover, selected publications on the use of this method were analysed. Then, an original, base model of forward-looking planning of technology development was constructed and presented. The end result of this process will be the development of the localized in time, presented in graphic form, action plan referred to as the route of technology development. Basing on the literature review and the research projects a preliminary route of development of arbitrarily chosen technology was also built and presented.

Keywords: foresight, Future-Oriented Technology Analysis (FTA), roadmapping, forward-looking planning.

JEL Classification: O32, Q42.

1. Introduction

With increasing demand for innovative technologies and broad trading market for technologies the issue of prospective planning of technology development is gaining importance. When reviewing literature it can be seen that the management of technology should be aimed at the identification and exploitation, but also the selection, acquisition, protection and acquiring of knowledge, undertaken in order to achieve and maintain a high market position of the organization (Cetindamar *et al.* 2009; Gregory 1995; Rush *et al.* 2007).

The identification process involves taking actions to acquire new technologies that would improve the competitiveness of the organization or to prevent its deterioration. Due to the importance of technology to the organization, the processes of obtaining it should be implemented in a planned and systematic manner. The selection is based on identifying the technologies with the greatest potential for development with respect to future economic, technological, environmental, social trends. On the basis of the selected technologies research and development priorities can be generated and applied in the form of research and development efforts, the results of which, when put into practice will allow in the future to achieve the target level of technological development and the provision of e.g. a development and competitive technological portfolio to a company (Nazarko 2013). The acquisition of pre-selected technologies involves making a decision on the purchase or implementation of technology (Nazarko *et al.* 2011). In contrast, exploitation of technology involves the use of technology in order to provide financial or non-financial benefits for the company. In turn the process of technology protection is associated with the protection of unique of industrial and intellectual property of a company. In turn knowledge acquisition is conditional upon, inter alia, the development and exploitation of technology. The acquisition of a given technology involves most frequently incurring high costs and the use of significant resources of the organization. Therefore, it seems reasonable to examine how the selected technology will evolve over time. Therefore, according to the author, in the structure of technology management another important process involved in the planning of the development of technologies needs to be extracted (Halicka 2014b). The process should include both the current development trends enabling extrapolation for the immediate future and long-time horizons.

Effective planning of technology development is difficult due to the cost, complexity, and pace of technological change on the global market. Prospective planning of the technology development for the benefit of the national economy and its individual entities requires the use of specific systems and processes, which make the investment in research and development, facilities and qualifications of the staff to be tailored to the needs of the market and industry, both now and in the long-term perspective. Those conditions justify the use of future-oriented technology analysis tools (Future-oriented Technology Analysis). FTA is a systematic process of technology characterization and the identification of their development paths and potential impacts, especially in the future. This approach combines technology assessment and foresight activities with foresight and technology intelligence (Gudanowska 2014).

The purpose of this article is to present the Future-Oriented Technology Analysis (FTA) methodology as a method applicable in technology/technologies management, and in particular in the planning of the technology development. The authorial, base model of technology development planning was also presented in the article. The end result of this process will be the development of the localized in different time horizons, presented in a graphic form, action plan. Basing on the literature review and the research projects a preliminary route of development of arbitrarily chosen technology was also built and presented in further research.

2. Idea of FTA

The term FTA was first used in 2004 in the seminar on New Horizons and Challenges for Future-Oriented Technology Analysis: New Technology Foresight, Forecasting and Assessment organised by the Institute for Prospective Technological Studies (IPTS).

The main objective of the Seminar was to analyse possible overlapping fields of practice among technology foresight, forecasting, intelligence, roadmapping, and assessment. Over time the term was used to describe a set of disciplines and methods, which try to better understand and shape the future from different methodological perspectives" (Haegeman *et al*. 2013). According to Cagnin and Keenan (Cagnin *et al*. 2008) FTA is: a common umbrella term for technology fore-sight, technology forecasting and technology assessment. Future-oriented technology analysis includes 50 methods making up 13 "methods families" (Table 1).

Table 1. Future-oriented technology analysis methods (source: Cagnin *et al*. 2008)

No	Methods families	Sample methods
1	Creativity approaches	TRIZ, future workshops, visioning
2	Monitoring and intelligence	technology watch, tech mining
3	Descriptive	bibliometrics, impact checklists, state of the future index, multiple perspectives assessment, literature review
4	Matrices	analogies, morphological analysis, crossimpact analyses
5	Statistical analyses	risk analysis, correlations
6	Trend analyses	growth curve modelling, leading indicators, envelope curves, long wave models
7	Expert opinion	survey, delphi, focus groups, participatory approaches
8	Modelling and simulation	innovation systems descriptions, complex adaptive systems modelling, chaotic regimes modelling, technology diffusion or substitution analyses, input-output modelling, agent-based modelling
9	Logical/causal analyses	requirements analysis, institutional analyses, stakeholder analyses, social impact assessment, mitigation strategizing, sustainability analyses, action analyses, relevance trees, futures wheel
10	Roadmapping	backcasting, technology/product roadmapping, science mapping, multi-path mapping
11	Scenarios	scenario management, quantitatively based scenarios, different emphases, science theatres, video
12	Valuing/decision-aiding/economic analyses	cost-benefit analysis (CBA), SWOT, analytical hierarchy process (AHP), data envelopment analysis (DEA), multicriteria decision analyses
13	Combinations	scenario-simulation (gaming), trend impact analysis

According to the author FTA is to collect a set of useful tools which can be used successfully in perspective predicting of technology development. Not all methods listed in Table 1 are suitable for management, planning technology development. It is difficult, however, to choose among the dozens of methods used in the FTA – especially by inexperienced researchers – those that will be useful for predicting technology development. It is therefore appropriate to prepare a prospective model of technology development planning. This model should contain the stages of research proceedings seeking the future-oriented technology development planning. This model should also include methods useful for the implementation of each step.

In order to develop such a model, the author analysed the database of scientific IEEE and Web of Science publications, in terms of procedure, scope and frequency of the use of Future-Oriented Technology Analysis. The choice of databases was dictated by their availability. Based on a search of databases using keywords such as future-oriented technology analysis, in the last ten years, 45 articles were identified (Fig. 1).

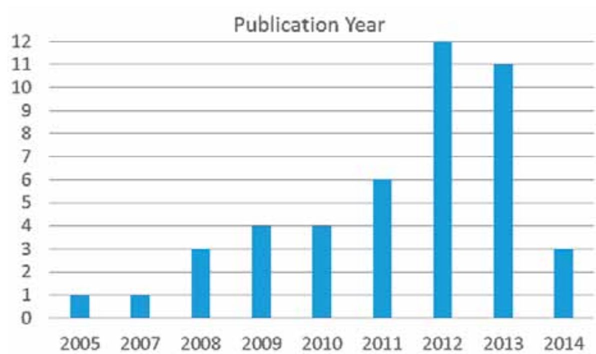

Fig. 1. Number of publications in the database IEEE and WEB of Science on FTA (source: own study based on the review of literature)

Analysing Figure 1, it can be concluded that the interest in the subject is steadily increasing, and since 2012, there have been over 10 newly created publications in this field every year. Then, the citation index in the Web of Science database (Fig. 2) was checked, and a systematic increase in citations of publications associated with the FTA was observed. The most cited publications were analysed, and it can stated that they are of application nature, the usage of the FTA method is presented there. The most cited article is the publication from 2008 (Robinson, Propp 2008) associated with the use of the FTA for the construction of the emerging technologies' development strategy.

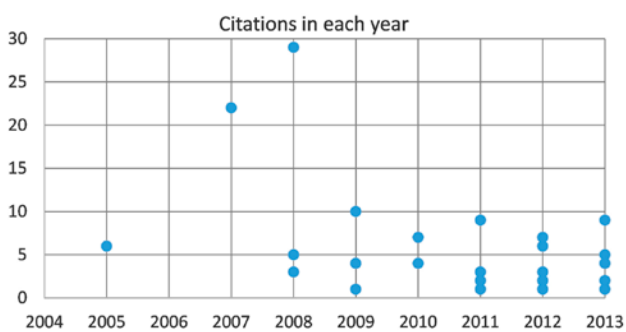

Fig. 2. Citations in each year (source: own study based on the review of literature)

All the collected publications were analysed in detail and a classification by the nature of the article was performed:

(1) methodological – where the FTA methods or their modifications were presented;

(2) review – a review of methods, classification, description, etc., were performed;

(3) application – where the application of the FTA method was presented (Guo *et al.* 2011; Huang *et al.* 2011; Marinho, Cagnin 2014; Markus, Mentzer 2014).

Definitely, most of the articles are reviews (25 articles); methods were reviewed, classified, and the possibility of their use was also presented (Amanatidou *et al.* 2012; Boden *et al.* 2012; Cagnin *et al.* 2013; Eerola, Miles 2011; Georghiou, Harper 2013). On the other hand, the least articles are applications – only 8 articles. Most commonly, this method is used in the field of nanotechnology to predict the development of new and emerging science and technologies (Alencar *et al.* 2007; Damrongchai *et al.* 2010; Huang *et al.* 2012; Koivisto *et al.* 2008; Robinson *et al.* 2013; Schaper-Rinkel 2013).

By analysing publications in detail, comparing them with Table 1, the author noticed the most commonly used methods belonging to groups: descriptive, monitoring and intelligence, expert opinion, scenarios, roadmapping. The methods from other groups (creativity approaches, matrices, Statistical Analyses, Trend Analyses, logical/causal Analyses, valuing/Decision-Aiding/economic Analyses) are used sporadically (Gesche *et al.* 2012; Magruk 2011; Weber *et al.* 2012).

According to the author, in technology development planning, the tools for accurately describing, understanding the technology are of great importance (Gudanowska 2013). However, taking into account Table 1, it can be seen that these tools have been treated rather marginally. The model of prospective technology management, proposed by the author, includes these methods.

3. The characteristics of the prospective technology development planning process

Based on a detailed analysis of publications, a base model of prospective technology development planning was established. Figure 3 shows the process enabling foresight to anticipate the development of technology.

The model of prospective planning of technology development consists of three consecutive stages. The first stage consists primarily of analysing and understanding the collected technologies. At this stage, the current state and the current possibilities of application of technology will be examined. An analysis of the life cycle of technology will be conducted and technological the Technology Readiness Level will be determined. The LCA method allows the diagnosis of the market age of technologies. Within LCA analysis the following elements can be distinguished: (1) core technologies – widely used in the sector, available with light and weakening competitive value; (2) key technologies – underlying competitiveness, strongly protected; (3) experimental technologies with little application, which may in the future become key technologies. In turn, by using the method of TRL, the categorization of the level of technology development will be possible, so that you can determine its current state and prospects of development according to the accepted scale uniform for all the analysed technologies. The end result of this step will be the development of a directory of key technologies.

In the next stage, only the key technologies selected in the first stage will be analysed in detail based on bibliometrics analysis, source data analysis, patent analysis, literature review. Bibliometrics analysis allows to determine the state of technology through research using quantitative (statistical) methods – on the basis of descriptions and bibliographies, research of the content of full-text literature databases, scientific citation indexes and statistics on publications – scientific and technical literature in the field of the ongoing research. In turn, source data analysis involves the analysis of statistical data and analysis of the literature. The result of this method may be a project including the diagnosis of the current state of technology development. In contrast, patent analysis focuses primarily on finding, analysing technical information, and enables the identification of gaps in the area of intellectual property, identification of key authors, inventors and owners of the rights to innovation in a particular area. Honest review of the literature is an introduction to the current state of knowledge on the topic. It is based on a logical, reflective approach, based on an analysis of prior knowledge regarding the study area, and contained in scientific publications, books, reports, articles. In stage 2, using the above- mentioned methods, areas/spheres/layers will be proposed, that influence the development of technology, such as resources. In the model, this step is conventionally called the designation of areas/spheres/layers. This step will also identify the potential application of key technologies. At this stage, the final result will be to establish the initial route of technology development. It is important for this route to present the current, objective and fair view of the technology. Therefore, it should be developed by an independent and impartial team. During the creation of the initial route, the opinions of the environment related to technological development should not be included. The effect of this stage is the result of a review of literature, patent databases and research reports.

The last stage (III) will involve, inter alia, verification of the base route developed in the previous stage. This time, the representatives of science (experts of the technologies) as well as decision-makers or entrepreneurs using technology will be invited to the research. The opinions of experts will be collected using the Delphi method. It is a tool enabling an effective communication in the group of experts, who remain anonymous to each other, in order to solve a complex problem. The persons whose competence in a particular area inspires confidence will be invited to the group of experts. It is expected that experts have knowledge of future trends in the development of the studied area and represent a broad perspective of thinking. Initially, Delphi questionnaire will be developed. Then the developed Delphi questionnaire will be sent to a wider group of experts. The task of the group of experts will involve filling in the questionnaire and making judgments about the development of selected technologies in a determined term. The filled in questionnaires will be collected, compared, summarized, and sent to the experts again. In the next round of the research the respondents will fill in the same questionnaire, whereas they have the opportunity to get acquainted with the collective results of the first round of research. Thus the experts have the opportunity to become acquainted with the opinions of other experts (but without the ability of contacting each other and establishing their personal details), they may modify, maintain and revise their previous opinions etc. The opinions of experts will help to complete the route, or to change the layers or the information provided in the individual layers (Nazarko *et al.* 2011).

The end result of the whole process will be the technology development route, which locates the development of technology in the time dimension, and allows for reflection of relationships that exist between the development of technology and progress in other areas. The route of technology development can present visions of development of selected technologies in terms of market, technological or human potential (Kim et al. 2010). The literature review indicates that the created development routes can also assume a different graphic form. They are presented in the form of histograms,

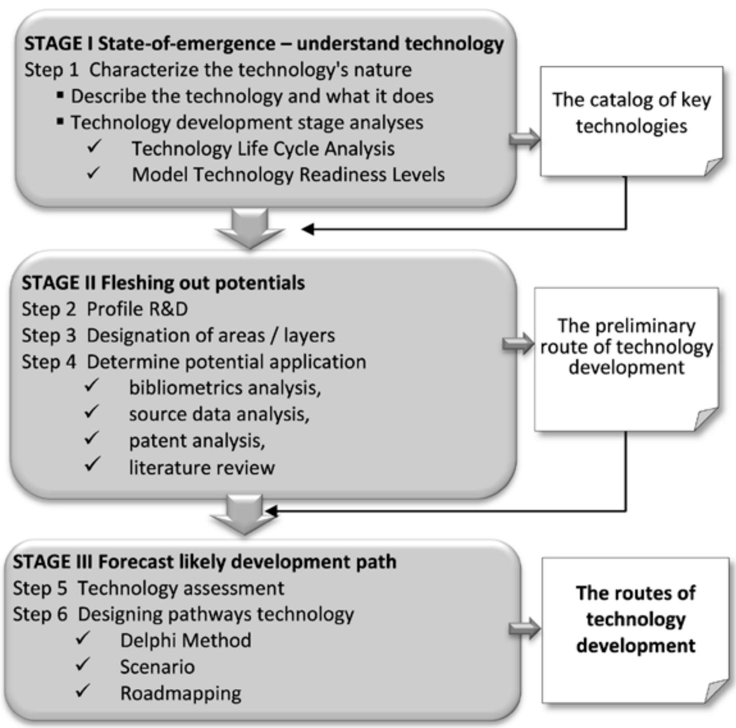

Fig. 3. The base model of the prospective planning of technology development (source: Halicka *et al.* 2015)

tables, graphs, flow diagrams or text. According to the author, presentation of the maps of technology development in the form of area charts is clear, easy to read and understand. The author also proposes to include the concept of R. Phaala in the design of routes of technology development, inter alia consisting in identification of: (1) the needs of industrial and scientific and research sector, the country of the organization; (2) products, services and projects that meet identified needs; (3) the directions of research allowing for development or production of new products and services; (4) the potential and resources that will allow for the implementation of the desired vision of development. Thus, the route of technology development – according to the author – should be presented in an area chart containing such layers as the market, products, technologies, research directions and resources.

Using the model shown in the picture later in the article, a preliminary development route of the arbitrarily chosen technology was developed – the result of phase II of the base model of prospective planning of technology development.

4. An example of the use of the base model of prospective technology planning

In this chapter to present the development of technologies the methodology proposed in the previous chapter was used. Due to the author's experience and knowledge in the area of the energy market, and in particular the renewable-energy sources, an initial technology development route for energy storage technologies – Lithium-ion (Li-ion) battery type was built (Halicka 2014a, 2014b, 2014c). These batteries have a very wide application. They can be used, inter alia, in electrical vehicles and for storing the energy from renewable energy sources (Electric Power Research Institute 2010; International Electrotechnical Commission 2011). The initial route was designed for the time horizon until the year 2030.

According to the model of a prospective technology management phase II is primarily based on a review of the literature, patent databases and reports of research on the chosen technology – in this case the battery Li-ion. As a result of a thorough analysis of the literature and research in the field the author proposed the route of development of the Li-ion battery was composed of four layers: technology resources, product, application, market drivers. The layer of market drivers should include social, political, legal or environmental (trends) conditions that influence the development of Li-ion batteries. In turn, the layer of technology resources will take into account technical and economic conditions that determine the development of the product layer, and this in turn will contribute to the development of the layer of application. Figure 4 shows the initial route of development of the Li-ion battery.

The initial route is the primary source of knowledge about the technology, it is a kind of knowledge base on technology, presented in a manner which is synthetic and easy

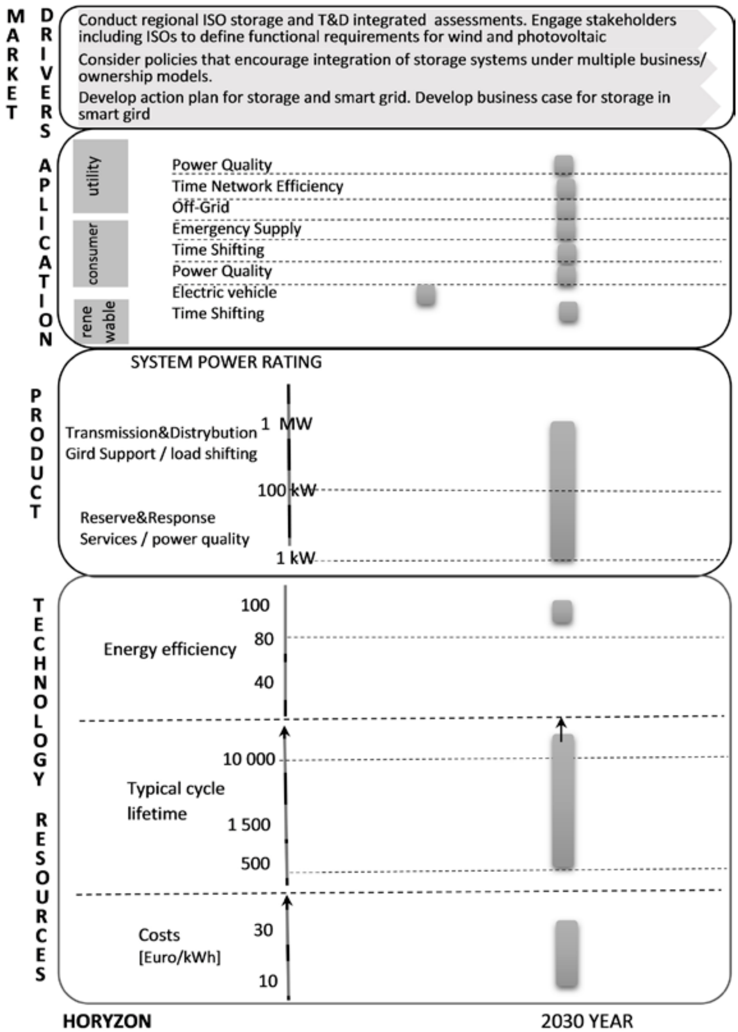

Fig. 4. The initial route of development of the Li-ion battery (source: Halicka *et al.* 2015)

to read. The reliably designed initial route will contribute to the improvement of the Delphi survey, and thus to preparation of the complete, final version of the development route of the selected technology.

The route of development of the Li-ion technology will be useful to producers of renewable energy who will use or intend to use batteries for energy storage. It will also be useful to battery manufacturers and researchers. The route also allows for summarizing, illustrating the barriers to the use of the technology, and this in turn may encourage researchers to conduct further studies allowing for the reduction of these restrictions.

It is also important to develop routes of similar technologies having similar properties, applications. Then it will be possible to compare these technologies. Therefore, the author recommends performing technology development routes of all the available energy storage technologies.

5. Conclusions

According to the model of a prospective technology management phase II is primarily based on a review of the literature, patent databases and reports of research on the chosen technology – in this case the battery Li-ion. As a result of a thorough analysis of the literature and research in the field the author proposed the route of development of the Li-ion battery was composed of four layers: technology resources, product, application, market drivers. The layer of market drivers should include social, political, legal or environmental (trends) conditions that influence the development of Li-ion batteries. In turn, the layer of technology resources will take into account technical and economic conditions that determine the development of the product layer, and this in turn will contribute to the development of the layer of application. Figure 4 shows the initial route of development of the Li-ion battery.

The initial route is the primary source of knowledge about the technology, it is a kind of knowledge base on technology, presented in a manner which is synthetic and easy to read. The reliably designed initial route will contribute to the improvement of the Delphi survey, and thus to preparation of the complete, final version of the development route of the selected technology.

The route of development of the Li-ion technology will be useful to producers of renewable energy who will use or intend to use batteries for energy storage. It will also be useful to battery manufacturers and researchers. The route also allows for summarizing, illustrating the barriers to the use of the technology, and this in turn may encourage researchers to conduct further studies allowing for the reduction of these restrictions.

It is also important to develop routes of similar technologies having similar properties, applications. Then it will be possible to compare these technologies. Therefore, the author recommends performing technology development routes of all the available energy storage technologies.

References

Alencar, M. S. M.; Porter, A. L.; Antunes, A. M. S. 2007. Nanopatenting patterns in relation to product life cycle. *Technological Forecasting And Social Change* 74(9): 1661–1680. http://dx.doi.org/10.1016/j.techfore.2007.04.002

Amanatidou, E.; Butter, M.; Carabias, V.; Koennoelae, T.; Leis, M.; Saritas, O.; Schaper-Rinkel, P.; van Rij, V. 2012. On concepts and methods in horizon scanning: lessons from initi-ating policy dialogues on emerging issues, *Science and Public Policy* 39(2): 208–221. http://dx.doi.org/10.1093/scipol/scs017

Boden, M.; Johnston, R.; Scapolo, F. 2012. The role of FTA in responding to grand challenges: a new approach for STI policy?, *Science and Public Policy* 39(2): 135–139.
http://dx.doi.org/10.1093/scipol/scs026

Cagnin, C.; Keenan, M.; Johnston, R.; Scapolo, F.; Barré, R. (Eds.). 2008. *Future-oriented technology analysis. Strategic intelligence for an innovative economy*. Springer-Verlag. 169 p.
http://dx.doi.org/10.1007/978-3-540-68811-2

Cagnin, C.; Havas, A.; Saritas, O. 2013. Future-oriented technology analysis: its potential to address disruptive transformations, *Technological Forecasting and Social Change* 80(3): 379–385.
http://dx.doi.org/10.1016/j.techfore.2012.10.001

Cetindamar, D.; Phaal, R.; Probert, D. 2009. Understanding technology management as a dynamic capability: a framework for technology management activities, *Technovation* 29(4): 237–246.
http://dx.doi.org/10.1016/j.technovation.2008.10.004

Damrongchai, N.; Satangput, P.; Tegart, G.; Sripaipan, C. 2010. Future technology analysis for biosecurity and emerging infectious diseases in Asia-Pacific, *Science and Public Policy* 37(1): 41–50.
http://dx.doi.org/10.3152/030234210X490778

Eerola, A.; Miles, I. 2011. Methods and tools contributing to FTA: a knowledge-based per-spective, *Futures* 43(3): 265–278. http://dx.doi.org/10.1016/j.futures.2010.11.005

Electric Power Research Institute. 2010. *Electricity energy storage technology options*. A white paper primer on applications, costs, and benefits.

International Electrotechnical Commission. 2011. *Electrical energy storage*. White paper, Switzerland, 92 p.

Georghiou, L.; Harper, J. C. 2013. Rising to the challenges-Reflections on Future-oriented Technology Analysis, *Technological Forecasting and Social Change* 80(3): 467–470.
http://dx.doi.org/10.1016/j.techfore.2012.10.009

Gesche, V. N.; Frese, J.; Koch, S.; Rongen, L.; Mela, P.; Jockenhoevel, S. 2012. Cell-based implants in heart surgery – opportunities and hurdles of this future oriented technology, *Endoskopie Heute* 25(4): 271–275.

Gregory, M. J. 1995. Technology management – a proces approach, *Proceedings of the Institution of Mechanical Engineers* 209: 347–356. http://dx.doi.org/10.1243/PIME_PROC_1995_209_094_02

Gudanowska, A. E. 2014. Mapowanie technologii jako jedna z metod analizy technologii w świetle wybranych zagranicznych doświadczeń [Technology mapping as a method of technology analysis in the light of selected foreign experiences], *Ekonomia i Zarządzanie* [Economics and Management] 6(1): 265–281. http://dx.doi.org/10.12846/j.em.2014.01.16

Gudanowska, A. 2013. Technology mapping in foresight studies as a tool of technology management – Polish experience, *Współczesne Zarządzanie* 4: 61–72.

Guo, Y.; Wang, X.; Zhu, D. 2011. Innovation risk-utility pathway method applied to dye-sensitized solar cells, in *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM),* 6–9 December 2011, Singapore, Singapore, 1305–1308.

Haegeman, K.; Marinelli, E.; Scapolo, F.; Ricci, A.; Sokolov, A. 2013. Quantitative and qualitative approaches in Future-oriented Technology Analysis (FTA): from combination to integration?, *Technological Forecasting and Social Change* 80(3): 386–397. http://dx.doi.org/10.1016/j.techfore.2012.10.002

Halicka, K. 2014a. Designing routes of development of renewable energy technologies, *Procedia – Social and Behavioral Sciences* 156: 58–62. http://dx.doi.org/10.1016/j.sbspro.2014.11.119

Halicka, K. 2014b. Zarządzanie technologiami z wykorzystaniem metody technology roadmapping, *Zeszyty Naukowe Politechniki Śląskiej nr 1919: seria Organizacja i Zarządzanie* 73: 211–223.

Halicka, K. 2014c. Priorytetowe technologie polskiej energetyki w perspektywie 2030 roku [Polish power energy priority technologies in 2030 perspective], *Przegląd Elektrotechniczny* 9: 105–108.

Halicka, K.; Lombardi, P. A.; Styczynski, Z. 2015. Future-oriented analysis of battery technologies, in *IEEE International Conference on Industrial Technology (ICIT) 2015*, 17–19 March 2015, Seville, 1019–1024. http://dx.doi.org/10.1109/ICIT.2015.7125231

Huang, L.; Guo, Y.; Peng, Z.; Porter, A. L. 2011. Characterising a technology development at the stage of early emerging applications: nanomaterial-enhanced biosensors, *Technology Analysis & Strategic Management* 23(5): 527–544. http://dx.doi.org/10.1080/09537325.2011.565666

Huang, L.; Guo, Y.; Youties, J.; Porter, A. L. 2012. Early commercialization pattern profiling: nano-enhanced biosensors, *PICMET '12: Proceedings – Technology Management for Emerging Technologies,* 29 July – 2 August 2012, Vancouver, BC, 2612–2624.

Kim, S.-Y.; Lee, J.-W.; Lee, O.-S.; Ahn, E.-Y.; Park, B.-W.; Hwang, K.-H. 2010. Technology strategy and roadmap for georesource development in Korea, *Smart Science For Exploration And Mining* 1–2: 985–987.

Koivisto, R.; Wessberg, N.; Eerola, A.; Ahlqvist, T.; Kivisaari, S.; Myllyoja, J.; Halonen, M. 2008. Integrating future-oriented technology analysis and risk assessment methodologies, *Technological Forecasting and Social Change* 76(9): 1163–1176. http://dx.doi.org/10.1016/j.techfore.2009.07.012

Magruk, A. 2011. Innovative classification of technology foresight methods, *Technological and Economic Development of Economy* 17(4): 700–715. http://dx.doi.org/10.3846/20294913.2011.649912

Marinho, S. V.; Cagnin, C. 2014. The roles of FTA in improving performance measurement systems to enable alignment between business strategy and operations: insights from three practical cases, *Futures* 59: 50–61. http://dx.doi.org/10.1016/j.futures.2014.01.015

Markus, M. L.; Mentzer, K. 2014. Foresight for a responsible future with ICT, *Information Systems Frontiers* 16(30): 353–368. http://dx.doi.org/10.1007/s10796-013-9479-9

Nazarko, J.; Dębkowska, K.; Ejdys, J.; Glińska, E.; Halicka, K.; Kononiuk, A.; Olszewska, A.; Gudanowska, A.; Magruk, A.; Nazarko, Ł. 2011. *Metodologia i procedury badawcze w projekcie Foresight Technologiczny NT for Podlaskie 2020: regionalna strategia rozwoju nanotechnologii* [Methodology and research procedures in the NT Technology Foresight for the Podlaskie 2020 project: regional strategy for the development of nanotechnology]. Białystok: Oficyna Wydawnicza Politechniki Białostockiej.

Nazarko, J. 2013. *Regionalny foresight gospodarczy. Metodologia i instrumentarium badawcze* [Regional economic foresight. Methodology and research instruments] [online]. Warszawa: ZPWiM [cited 17 August 2015]. Available from Internet: http://pbc.biaman.pl/dlibra/docmetadata?id=23865&from=&dirids=1&ver_id=&lp=1&QI=

Robinson, D. K. R.; Huang, L.; Guo, Y.; Porter, A. L. 2013. Forecasting Innovation Pathways (FIP) for new and emerging science and technologies, *Technological Forecasting and Social Change* 80(2): 267–285. http://dx.doi.org/10.1016/j.techfore.2011.06.004

Robinson, D. K. R.; Propp, T. 2008. Multi-path mapping for alignment strategies in emerging science and technologies, *Technological Forecasting and Social Change* 75(4): 517–538. http://dx.doi.org/10.1016/j.techfore.2008.02.002

Rush, H.; Bessant, J.; Hobday, M. 2007. Assessing the technological capabilities of firms: developing a policy tool, *R&D Management* 37(3): 221–236. http://dx.doi.org/10.1111/j.1467-9310.2007.00471.x

Schaper-Rinkel, P. 2013. The role of future-oriented technology analysis in the governance of emerging technologies: the example of nanotechnology, *Technological Forecasting and Social Change* 80(3): 444–452. http://dx.doi.org/10.1016/j.techfore.2012.10.007

Weber, K. M.; Harper, J. C.; Koennoelae, T.; Barcelo, V. C. 2012. Coping with a fast-changing world: towards new systems of future-oriented technology analysis, *Science and Public Policy* 39(2): 153–165. http://dx.doi.org/10.1093/scipol/scs012

Katarzyna HALICKA. PhD, since 2008 is an assistant professor at the Faculty of Management and Finance at the Bialystok University of Technology. Deputy Head of the Department of Business Informatics and Logistics and an editor of the logistics management section of the Economics and Management Journal. Author of about 60 scientific articles. Research interests: forecasting, foresight studies, technology management, methods of artificial intelligence.