Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 182 (2017) 247 – 254

Procedia Engineering

www.elsevier.com/locate/procedia

7th International Conference on Engineering, Project, and Production Management

Modern Research Trends within Technology Management in the Light of Selected Publications

Alicja E. Gudanowska*

Faculty of Management, Bialystok University of Technology, Wiejska 45A, 15-351 Bialystok, Poland

Abstract

The author of this article highlights the exploration for contemporary research trends within technology management. Thereby, this paper primarily focuses on investigating research areas and issues connected with technology management in contemporary scientific publications selected from the Web of Science database. The results of the undertaken overview of the selected literature lead to a visualisation of issues most frequently occurring in configuration with technology management, as well as the aspect of their coexistence in the analysed compilation of literature. Along with the description of the conducted analysis, it constitutes a fundamental result of this work.

Peer-review under responsibility of the organizing committee of EPPM2016

Keywords: technology; technology management; research trends; visualisation of knowledge

1. Introduction

Technologies, as a dominating factor in shaping the competitiveness of enterprises, require a careful insight into the scope their development. It is both crucial to identify available technologies (including their assessment), select appropriate solutions as well as perform activities connected with chosen technologies. Modern enterprises are forced to monitor emerging market trends within new technologies [1, 2]. The enormity of appearing technological solutions also necessitates the need to estimate their value, accounting for the complexity of technologies, their systematic character and relation. Customer expectations and needs determine shortening of the product's life cycle, as well as the cycle of technology application. Technologies become a dominating element in raising competitiveness of the

* Corresponding author. Tel.: +4-885-746-9896; fax: +4-885-663-2683.
E-mail address: a.gudanowska@pb.edu.pl

Peer-review under responsibility of the organizing committee of EPPM2016
doi:10.1016/j.proeng.2017.03.185

enterprises that use them. Observing the development of technologies, in turn, protects the interrelated investments to some extent. It appears logical to necessitate the search for the adequate mode of technology management.

The interest in technology management as a research field has grown considerably, particularly in the last decade, though it already dates back to the 1950s. This interest became an independent discipline together with the appearance of professional organisations, such as PICMET (*Portland International Centre for Management of Engineering and Technology*) and EITIM (*European Institute for Technology and Innovation Management*), [3]. According to Beyan and Cetindamar, the number of papers on this issue published in the years 1995-2005 grew by over 160%, as compared to preceding years (since 1986), [4]. In 1994 Tschirsky already indicated that technology management, apart from the need to understand the scope and potential of both current and future technologies, as well as the development of methods increasing the credibility of decisions connected with technologies, is one of the main research and practical areas of interest within technological changes and advancement [5]. While analysing a number of publications (Fig. 1) indexed in the Web of Science (WoS) database and referring to the concept of technology management, a growing interest into this issue can also be observed. The database provides access to multidisciplinary research connected with linked content citation metrics from multiple sources.

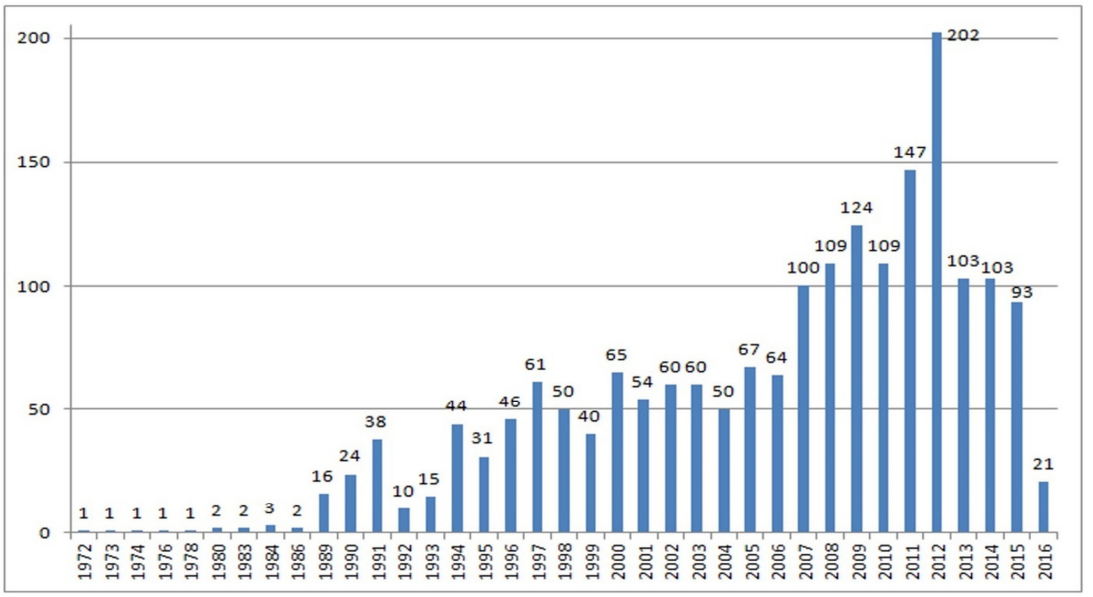

Fig. 1. Number of publications indexed in the Web of Science (WoS) database and referring to the concept of technology management.

It can be observed that a significant growth in the interest into the concept of technology management in the context of indexed publications in WoS took place after year 2006. In 2012, this issue attracted a range of considerations in scientific papers. In subsequent years, the number of publications on this topic oscillated around a constant number of papers. The issue of technology management has been undertaken by researchers publishing their papers in various periodicals, though there also exist magazines that issue publications on that matter more frequently (like *Procedia Social and Behavioral Sciences*, *International Journal of Technology Management*, *IEEE Transactions on Engineering Management*, *Technovation*, *Journal of Engineering and Technology Management, Technology Analysis Strategic Management* or *Technological Forecasting and Social Change*). Among the authors publishing in magazines indexed in WoS there are also scientists that both often raised the issue of technology management and have their papers cited in other works within this scope. These are: R. Phaal, D. Probert, C.J.P. Farrukh, D. Cetindamar, B. Yu, W.W. Wu and others.

2. The core of technology management

According to Łunarski, technology management entails all activities within management that determine the application of technological policy, objectives and responsibility, as well their execution within an organisation with the use of such means as: planning, ensuring resources, organising, steering the development of technology and its improvement in the application processes [6]. Technology management was also defined by The Task Force on Management of Technology as a process involving planning, development and execution of technological capabilities in order to shape and achieve strategic and operative objectives of an organisation [7]. The subject of technology management within this framework entails technological capabilities of a given organisation, in other words, an available portfolio of technologies [8]. The above cited definition frequently appears in literature. However, Cetindamar et al. claim that, despite encompassing both the "hard" and "soft" dimension of the technology, it only constitutes a statistical framework of the issue and fails to account for a dynamic character of the process. The authors indicate that the analysis of technology management necessitates the context of registration of the challenges and development opportunities of a new product created by the technological progress, as well as the diversification of the industry [3, 10]. In the context of observations made by Gregory [9], Cetindamar et al. described technology management as oriented at an effective execution, specific activities (listed in Table 1) undertaken in order to achieve and maintain (or grow) a high market position, based on the objectives of the organization [11]. Their technology management framework (Fig. 2) presents a dynamic character of the process of technology management, at the same time focusing on the adequate relations between technological resources and objectives of the enterprise. This requires effective communication, highly developed skills of dialoguing, understanding as well as effective management of the available knowledge [3]. This approach also indicates two mechanisms – technology push and market pull, according to which, technology might be an effect of research projects conveyed in scientific units or might be a response to emerging entrepreneurs and society demand for concrete solutions.

Table 1. Technology management framework activities.

Activities	Short description
Identification of technologies	technologies having a real or potential significance to the enterprise, involving searching, controlling, gathering information and its processing
Selection of technologies	technologies requiring decision making, preceded by determining priorities accepted by an enterprise at a strategic level, which allows for referring identified technologies to a business strategy
Acquisition	acquisition of previously selected technologies, decisions concerning the acquisition refer to the choice between the purchase, cooperation or the execution of a technology
Exploitation	exploitation of technologies in order to provide financial or other benefits to the enterprise
Protection	protection of knowledge and experience gathered in the production process
Learning	Learning the knowledge coming from the development and exploitation of technologies, where a strong relation to managing the knowledge in an organisation is observed

Source: [3].

It is to be noted that technology management should not be limited to managing a specific set of technologies, but also develop the strategy of their implementation in the aspect of available resources, currently used technologies, the future of the market and a social and economic environment [12, 13]. According to Badawy, technology management comes down to the practice of integrating a technological strategy into the business strategy in a company, an integration requiring a reasoned coordination of research and production, as well as the function of marketing, finances and human resources in a company [14]. Klincewicz identifies the fields of interest within which the researchers focused on technology management: (1) an aspect of appearing new technologies and their impact on current activities and development of the enterprise; (2) an identification of opportunities and threats in the context of development of technologies, particularly emerging ones; (3) decision making within conducting and coordinating individual research and development activities as well as the development of technological products, or (4) the protection of industrial and intellectual property of an enterprises [15]. According to the research conducted by Cetindamar at al., the basic topics within the scope of interest of the authors dealing with technology management are as follows: (1) the

organisation, its culture, structure, competences, knowledge, creativity, idea of management; (2) policy within technology, i.e. policies and systems of technology management, systems of innovation in the national, regional and sector framework; (3) the acquisition of the technology, its transfer, diffusion, adaptation, dissemination [16].

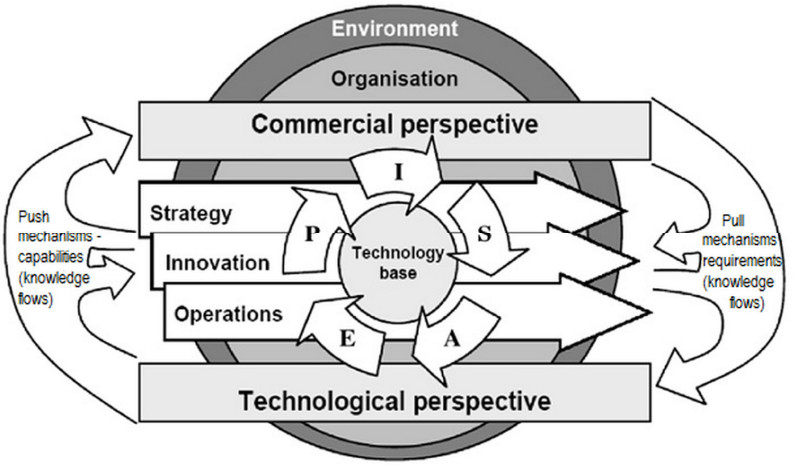

Fig. 2. Technology management framework.
Source: [3].

3. Research trends within technology management

3.1. The assumed research procedure

The author of the paper decided to investigate which research topics are connected with the concept of technology management with reference to a selected group of publications. The assessment was made on the basis of the Web of Science database. WoS Core collection provided articles, proceedings papers, books and book chapters that referred to technology management. This led to the identification of almost 2,000 papers that were subsequently used for preparing a map of research trends within technology management.

The analysis primarily focused on verifying which research areas concerned a list of publications selected from the database. Most papers were divided in two categories: business economics (467 publications) and engineering (435 publications). Most papers were also classified into the fields of: operations research management science (213), computer science (181) and information science library science (77). Other areas, where the number of papers oscillated between 10 and 50 articles, are: public administration, science technology other topics; environmental sciences ecology; education educational research; telecommunications and radiology nuclear medicine medical imaging.

Due to the growing interest in the issue of technology management in 2007 (Fig. 1), further considerations were made on the basis of two periods: before 2007 and in the years 2007-2016. The tool used for ordering and presenting data was VOSviewer programme. This software is particularly useful in the case of working with the sheer volume of data. With this program it is also possible to generate given map from several perspectives. Every prospect gives the opportunity to focus more on the occurrence of individual network components, while at the same time providing the information of their co-occurrence. The label view chosen for the purpose of this article, also allows presenting the clusters created out of co-occurring elements, by labeling them with colors corresponding to their affiliation. It is worth mentioning that visible bundles reflect the correlations that happen most frequently. If one component happens to be a part of several clusters, it is labeled only as the element of the group, in which it appears most often [17].

The analysis also necessitated the preparation of maps encompassing the co-occurrence of the authors' keywords. With the use of the WoS database, the author identified 809 articles connected with the issue of technology management. The analysis involved keywords indicated by the authors of the publications. With regard to the clarity

of the visualisation, this paper focuses on those expressions that appeared at least four times in a group of selected publications. Subsequently, the analysis disregarded the terms *technology management, management of technology*, *technology* and *management*, which constituted filters while selecting specific publications. Another prepared visualisation was the map of research trends connected with the issue of technology management in the period 2007-2016. The number of articles subjected to the analysis in this period was 1111. Also here, for the sake of the clarity of the visualisation, only those among authors' keywords were selected that occurred at least four times in the group of analysed publications. Filtering expressions were disregarded as well.

The size of the elements presented on the maps denotes the occurrence of particular keywords, whereas the connections between the knots of the resulting web point to their co-occurrence in an analysed group of articles. The stronger the connection, the higher the frequency of the co-occurrence.

3.2. Results

One of the prepared visualisations was the map of research trends connected with the issue of technology management in the period preceding year 2007. The resulting network of connections between analysed terms was presented in Fig. 3a. While analysing Fig. 3a, it can be observed that the resulting network is not so dense. Neither is it characterised by a large number of links between the nodes. This is not surprising, as already the number of publications in the analysed period indicated an initial development of the interest in the issue. However, there are clearly visible areas of research interests. The first research trend is an area connected with the issue of innovation. Above all, it was the most frequently occurring term. Innovation was the most popular subject of considerations in the context of a strategy, strategic management, new product development and technology acquisition. However, this term also co-occurred with the majority of other areas of research interests. These were: field connected with project management in the context of product development and innovation management, or an area referring to manufacturing and searching for advanced manufacturing technologies. Another research trend developed in the analysed period was technology strategy, combined with the process of strategic technology management or R&D management, as well as technology assessment or organisational culture. Another crucial area was an aspect of information technology that appeared most frequently in the context of case studies and implementation. Also the issue of technology transfer was often mentioned in the analysed period, and its context also involved the issue of intellectual property. The last research trend that can be identified at the analysed time was a barely emerging area of knowledge management connected with strategic planning, decision analysis and the context of information systems and the method of roadmapping.

The other prepared map (Fig. 3b) reflecting the network of research interests and encompassing the period between 2007-2016, is much more dense, more numerous in terms of connections between separate nodes than the first one. The overall image of the network indicates a larger number of undertaken research initiatives. The aspect of innovation remained stable as to comprising a context of the largest number of publications. It was associated with most issues undertaken within technology management. The trend connected with strategy and technology strategy appeared less significant. The aspect of knowledge management was developed to a great extent. Apart from innovation, it became one of the leading trends in the analysed period. It was most often connected with the contexts of sustainability, new product development and technology innovation. A similar development involved the aspect of innovation management that was mentioned in the context of technology selection and was as well connected with another, intensively developed, issue of information technology. The aspect of technology transfer, signalled in the previous period, also attracted researchers, especially in the combination with the issue of technology assessment, decision making and sustainable development. The trend of R&D management, apart from the mentioned aspect of product development, gained a new context of intellectual capital and human resources.

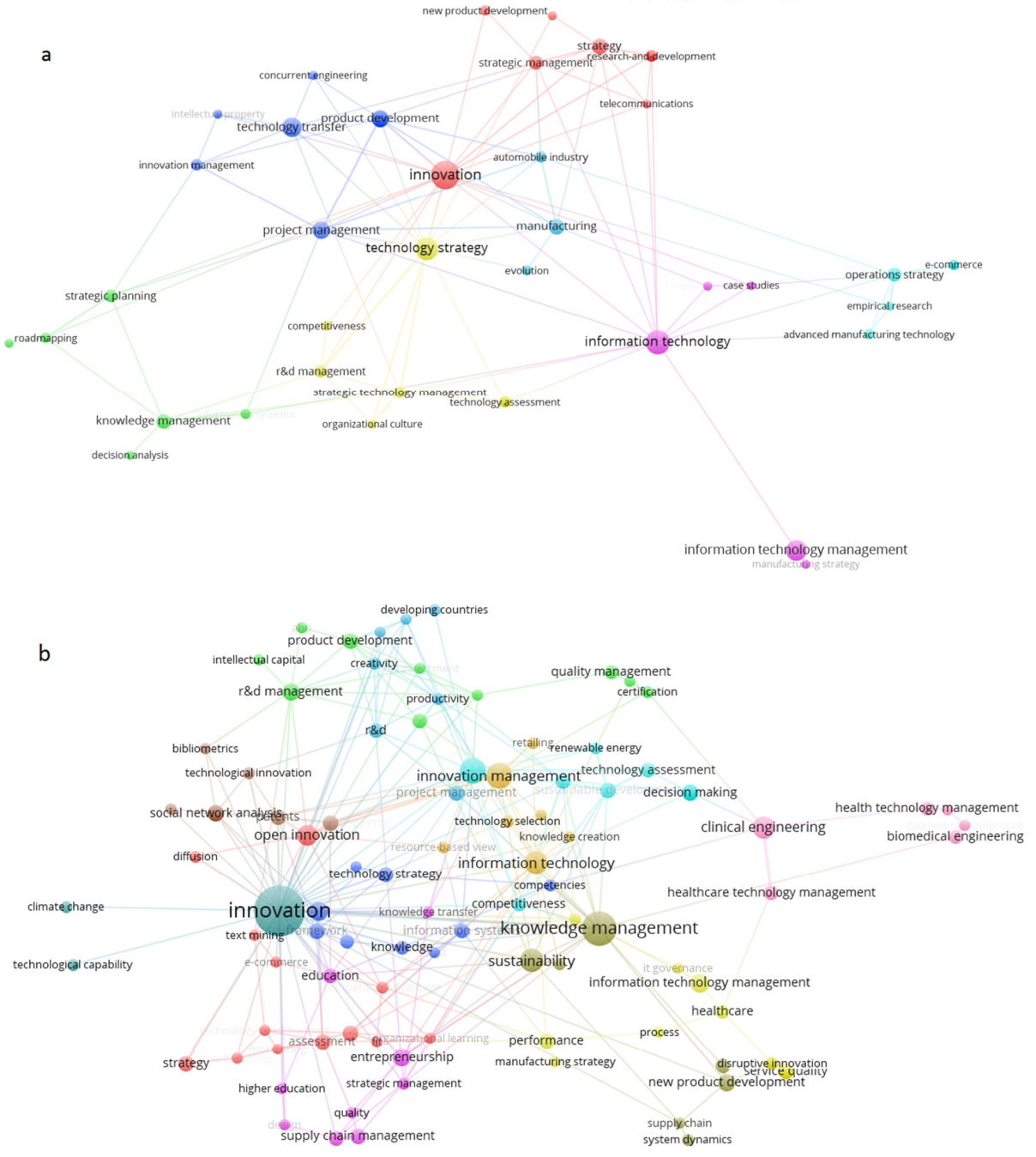

Fig. 3. Maps of co-occurrence of the authors' keywords in publications referring to technology management from the Web of Science database (a) before 2007; (b) in the years 2007-2016.

Here, a new issue of quality management became much more popular, combined with service operations and certification. The aspect of intellectual property, still mentioned and developed, was most often associated with the term patents. However, there appeared other new issues associated with bibliometrics and social network analysis.

A new issue, unobserved in the preceding period, was the aspect of open innovation or the context of education. An intensively developed, new trend that deserves attention is the area of health technology management together with clinical engineering. Apart from health there also occurred other areas, such as climate change and renewable energy that are reflected in scientific papers focused more on the practical application of aspects connected with technology management rather than the theoretical development of the concept itself.

4. Conclusion

Technologies comprise a dominating element in raising competitiveness of the enterprises that apply them. It is technology that modern enterprises base their activities on while creating a strategy that is to secure a competitive advantage and aiming at an adequate position on the market. Subsequently, the life cycles of both the product and technology use are shortened, and a great impact is placed on skilful technology management. Therefore it seems important to monitor emerging research trends undertaken within technology management.

The article analyses key words of the articles, which had been selected out of WoS database and divided into two time periods. That division was due to the analysis of the number of publications related to the topic of technology management, which appeared in the WoS database. The analysis was based on the key words given by the authors, as on the best, suitable descriptions of the contents of the analyzed articles. Key words reflect the interest of researchers in certain areas and therefore trends in fields of the topics of their publications.

Conducted analysis covering trends in publications related to the topic of technology management provided some interesting conclusions. It is noticed, that with the passage of time and increased number of publications also increased the number of areas in which the concept of technology management has been applied. A few research trends, in which scientists from the field of technology management have been interested, still maintain their process of continuous development. Terms like *innovation* or *product development* proved to be inseparable with the concept of technology management. Other issues, as for example knowledge management, have been evolving from being the secondary, complementary area of interest to becoming one of the main research trends. Many interesting research areas appeared during the second part of analysed time period (2007-2016), which over the following years might also grow into the next main research trends. These include, for instance, the network analysis in the context of intellectual property and technology innovation, or the usage of technology management in the field of healthcare and quality management. It is noticed, that researches mostly focus on the aspects of usage of the TM approach in various research areas, rather than on the development of the concept itself. This trend is likely to be maintained for the next few years.

The results and observations presented in the article provide a contemporary picture of modern trends within technology management. The analysis led to noting some new trends, which with previously indentified areas of interest create new interdisciplinary research directions. The executed analysis suggests that the search for new idea and solutions in the next few years is needed; solutions that will develop the aspect of identification and selection of the innovative technologies, as well as for the effective knowledge sharing in the area of a whole process of technology management. It also allows pointing the technology management as a rapidly developing field of study, characterized by interdisciplinary issues with a great research potential.

Acknowledgements

The research was conducted within S/WZ/1/2014 project and was financed from Ministry of Science and Higher Education funds.

Ministry of Science and Higher Education
Republic of Poland

7th International Conference on Engineering, Project, and Production Management (EPPM2016) was financed in the framework of the contract no. 712/P-DUN/2016 by the Ministry of Science and Higher Education from the funds earmarked for the public understanding of science initiatives.

7th International Conference on Engineering, Project, and Production Management (EPPM2016) finansowana w ramach umowy 712/P-DUN/2016 ze środków Ministra Nauki i Szkolnictwa Wyższego przeznaczonych na działalność upowszechniającą naukę.

ARiMR

7th International Conference on Engineering, Project, and Production Management (EPPM2016) was co-organised by the Agency for Restructuring and Modernisation of Agriculture (Poland).

References

[1] Halicka K. Innovative Classification of Methods of The Future-Oriented Technology Analysis. *Technological and Economic Development of Economy* 2016;22(4):574–597.

[2] Halicka K, Lombardi PA, Styczyński Z. Future-oriented analysis of battery technologies. *IEEE International Conference On Industrial Technology (ICIT)* 2015;1019–1024.

[3] Cetindamar D, Phaal R, Probert D. Understanding technology management as a dynamic capability: A framework for technology management activities. *Technovation* 2009;29:237–246.

[4] Beyhan B, Cetindamar D. No escape from the dominant theories: The analysis of intellectual pillars of technology management in developing countries. *Technological Forecasting and Social Change* 2011;78:103–115.

[5] Tschirsky HP. The role of technology forecasting and assessment in technology management. *R&D Management* 1994;24(2):121–129.

[6] Łunarski J. *Zarządzenie technologiami. Ocena i doskonalenie* [Technology management. Evaluation and improvement]. Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej; 2009.

[7] NRC/National Research Council. *Management of Technology: The Hidden Competitive Advantage*. Washington DC: National Academy Press; 1987.

[8] Chanaron JJ, Jolly D. Technological management: expanding the perspective of management of technology. *Management Decision* 1999;37(8):613–620.

[9] Gregory MJ. Technology management: a process approach. *Proceedings of the Institution of Mechanical Engineers* 1995;209:347–356.

[10] Phaal R, Farrukh CJP, Probert DR. Technology management process assessment: a case study. *International Journal of Operations & Production Management* 2001;21(8):1116–1132.

[11] Phaal R, Farrukh CJP, Probert DR. Technology roadmapping – A planning framework for evolution and revolution. *Technological Forecasting and Social Change* 2004;71:5–26.

[12] Nazarko Ł. Responsible research and innovation – new paradigm of technology management. *The 9th International Scientific Conference Business and Management 2016: Conference Proceedings*; 2016.

[13] Liao S. Technology management methodologies and applications. A literature review from 1995 to 2003. *Technovation* 2005;25:381–393.

[14] Badawy MK. Technology management education: alternatives models. *California Management Review* 1998;40(4):94–116.

[15] Klincewicz K. *Zarządzanie technologiami. Przypadek niebieskiego lasera* [Technology management. The case of blue laser]. Warszawa: Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego; 2010.

[16] Cetindamar D, Wasti SN, Ansal H, Beyhan B. Does technology management research diverge or converge in developing and developed countries? *Technovation* 2009;29:45–58.

[17] Van Eck NJ, Waltman L. *VOSviewer Manual. Manual for VOSviewer version 1.3.0*. software documentation; 2011.