

TECHNOLOGY MAPPING IN FORESIGHT STUDIES AS A TOOL OF TECHNOLOGY MANAGEMENT – THE POLISH EXPERIENCE

*Alicja E. Gudanowska**

Abstract

Background. Knowledge of technologies is one of the elements shaping economic growth. At the same time, current technologies are characterised by a growing complexity, and their application lifecycle is getting shorter. Observation and analysis of their development has become crucial in order to protect investments linked with them. There seems to be a logical need for both proper technology management and methodology development in that area to be constituted.

Research aims. The aim of the article is to present the problem of technology mapping in the scope of foresight studies as a tool of technology management. The main emphasis has been put on the identification, the subsequent analysis and the evaluation of the activities undertaken in the phase aimed at diagnosing the current state of technology in the context of foresight studies.

Method. Identification of foresight initiatives which undertake operations within the scope of diagnosis of the current state of technology has been conducted through observation, document analysis, literature analysis and review. Selection of the best practices among the identified ones has been made through the assessment of the degree to which criteria defined by the author were fulfilled.

Key findings. The fundamental result of the analysis conducted in the article is the identification of elements of diagnosis of the current state of technology, which can be held as recommendations in the scope of using the methodology of technology mapping. They comprise, among others, preparing technology cards, localising resources linked with technology, and the visualisation of possible relations among technologies.

Keywords: Technology mapping, Foresight, Diagnosis of current state of technology

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INTRODUCTION AND BACKGROUND

Due to the great significance attached to technology development as one of the elements driving contemporary economy, what seems vital is technology monitoring through observing its current state, as well as defining the possible occurring relations among technologies, so as to determine, ultimately, their development schemes. At the same time, the basic objective of most foresight research is supporting the making of strategic decisions (Matusiak, 2009, p. 8). Such analyses should be carried out comprehensively so that the fullest understanding is provided of the potential of

* Mgr Alicja E. Gudanowska, Białystok University of Technology.



the academic and technology sectors which are perceived as key for shaping scientific-technological policy (Gavigan & Scapolo, 1999, p. 496).

In light of the above, the author investigates the subject matter of determining the current state of technology within foresight research, which could be defined as technology mapping. In her opinion, it is an essential observation element and the basis of technological environment changes predictions. The analysis of the issue demanded a previous reference to the technology management process and clarification of the term of technology mapping and its position in foresight research.

The Process of Technology Management and Technology Mapping

Knowledge of technologies is one of the elements which shape economic development. However, modern technologies are characterized by their increasing complexity, and their application cycle has been getting shorter (Hejduk & Grudzewski, 2008). They are becoming a dominant component in the refinement of competitiveness of companies which exploit those technologies, and observation of technology development is a certain type of protection for investments related to those technologies. It seems like a logical need to constitute an adequate technology management method, just like in the cases of quality, the environment or safety (Łunarski, 2009, p. 4).

The notion of technology management functions in the literature is aimed at effective implementation of certain operations in order to achieve and maintain (or increase) a strong market position; it is based on the organisation's objectives (Phaal, Farrukh, & Probert, 2004, p. 7). The following operations in the scope of technology management are:

1. Technology identification which has a real or potential significance for the company and involves searching for information, its examination, collecting and processing;
2. Technology selection requiring the making of decisions; it is preceded by defining the priorities adopted by the company on the strategic level, allowing for the relating of identified technologies to the business strategy;
3. Acquisition of previously selected technologies;
4. Exploitation of technologies in order to provide the company with financial benefits or benefits of another type;
5. Protection of knowledge and experience gained in the production process.

A significant aspect of technology management, which complements the enumerated operations, is to learn from technology development and exploitation, where the strong relationship with knowledge management shows (Cetindamar, Phaal, & Probert, 2009, p. 242).



Using traditional planning, modelling and technology development forecasting in the scope of technology management should be assisted by the application of modern tools of future management (Magruk, 2011, p. 48), such as the ones used in foresight projects execution. At the same time, a great number of technologies emerging every day trigger the need for the estimating of their worth, so as the most promising technologies could be chosen and then developed (Pawlak, 2010). One of the foresight research methods which analyse the current state of technologies is technology mapping (Gudanowska, 2012). It is a tool for collecting and processing a vast knowledge on technologies. Although elements of diagnosis of the current state of technologies have appeared in numerous foresight projects, practices in that scope require notional as well as methodological specifying. Thus, in the latter part of the article, the author focuses on identification and critical analysis of Polish foresight practices in the scope of technology mapping.

Technology Mapping in Foresight Studies

A map is, by definition, an object representing a recorded picture of a given phenomenon. If the phenomenon is assumed to be a technology and its broad economic and social context highlighted in research, it is technology mapping that we are dealing with. In the Polish subject literature, in the context of methodology, and not just foresight methodology, that term often functions as an alternative term for technology roadmapping. However, as it emerges from the analyses conducted by the author in the scope of the nature and the course of the methods, perceiving those two terms as identical is unsubstantiated and the approach appearing in the Polish language seems to be an unnecessary simplification (Gudanowska, 2012). The term technology mapping is present in foreign literature as a separate method utilised in the initial stage of foresight research, referring to the static assessment of technology. Technology mapping can be placed in the first phase of foresight research systematization, the phase of understanding, which delivers entry data for the whole process. That phase precedes the other ones, namely the phase of synthesis and modelling, the phase of analysis and selection, the phase of transformation and the operational phase (Smith & Saritas, 2011).

The essence of the technology mapping method consists in an advanced diagnosis of the current state of technologies, in a way that allows for the identification, categorization and spatial location of technologies, and at the same time incorporating potential relationships among the technologies (Nazarko & Ejdyś, 2011, p. 23). The utilisation of the method should provide the largest possible knowledge base about technologies, comprising its various aspects, such as its maturity level, essential re-



sources connected with the development of the given technology, or its position in relation to other utilised technologies.

METHOD

In spite of the popularity of research on best practices identification, the lack of an unambiguous definition of best practice can be noticed. However, literature on the subject provides some clues on their choice and on the combination of criteria and attributes which characterise best practices. In the case of the analysis described in the publication, criteria choice and establishment were determined by the subject of these practices, namely the manner of conducting the diagnosis of the current state of technology in foresight research. It is vital that a best practice might not necessarily be constituted by an entirely completed project. An element of the adopted conduct might also be a best practice, adoptable in other conditions (Keehley, Medlin, MacBride, & Longmire, 1997; Yan & Chung-Hsing, 2011; Karwińska & Wiktor, 2008).

The work commenced with defining boundary conditions (Rogut, Piasecki, & Czyż, 2009, p. 15). These conditions assumed that (a) the analysed projects had to be foresight initiatives, (b) they were conducted in Poland, and (c) elements of defining the current state of technology were identified in them. The identification of operations focussed on the diagnosis of the current state of technology was conducted through observation, document analysis, literature analysis and review. The study allowed for the identification of 19 initiatives, within which documented operations were undertaken consistent with the adopted idea of technology mapping. Each of the practices was characterised (Table 1 presents the syntheses of the produced descriptions), and then the best practices were distinguished through the author's assessment of the fulfilment degree of the adopted criteria. The criteria included: (a) commonness of the given practice, defined as availability of documentation and clarity of produced descriptions, (b) repeatability of the practice, namely the possibility of applying it in a duplicated or modified form in another foresight project, also of a different specificity, (c) the practice had to be of a methodological preparation nature, and (d) the practice had to constitute an innovative perspective in comparison with other applied solutions. To complete, recommendations, summing up the wide examination conducted by the author, were prepared.



RESULTS

Identification of Polish Foresight Projects in which Methodology Consistent with Technology Mapping Was Used

In Poland, before 2012 over 40 foresight initiatives were undertaken, over half of the projects were of a technological nature. Studies and analyses conducted by the author imply that the aspect of defining current technologies states or analyses of their relationships were of interest to about 19 executors of Polish initiatives.

The author has identified elements consistent with the assumed technology mapping idea, including practice aimed at diagnosis of the current state of technology, which appears in the Polish projects. The list is presented in Table 1 and is an extension of a preliminary review presented in one of the author's previous works (Gudanowska, 2012).

Table 1. Polish foresight projects and the diagnosis of the current state of technology

Name of the Project	An element of the diagnosis of the current state of technology
Foresight of priority, innovative technologies for automation, robotics and measuring technology	Potential of individual voivodships in the scope of the analysed technologies in the form of description and registers (based on experts' opinions, literature analysis and conclusions from study trips and working meetings)
Regional foresight of the Zachodniopomorskie Voivodship	Analysis of publications and patents in chosen fields of chemistry
Technological foresight <<NT FOR Podlaskie 2020>> A regional strategy of nanotechnology development	Uniform technology cards, technology relationship maps, technology location maps
Technology foresight for industry INSIGHT 2030	Analysis of the current state of technology (based on expert opinions), an atlas of technology clusters
Technology foresight of public services development in Metropolitan Area of Upper Silesia	Diagnosis of the state and conditions of technology implementation in metropolitan services area; Questionnaire survey and analysis of enterprise needs (on the basis of a list of key factors and an innovation map)
Technology foresight for polymer materials	Technological review (analyses of available databases, publications, scientific and industrial periodicals and conference reports)
Foresight for priority and innovative technologies of hard bituminous coal mining waste management	Technology cards, expert analysis of technology innovation
Foresight for surface properties formation leading technologies of engineering materials and biomaterials	A database amassing data on technologies in the form of description cards



Name of the Project	An element of the diagnosis of the current state of technology
LORIS Vision. Regional technology foresight	Inventorying of existing knowledge reserves, a regional technological profile, network analysis was also conducted in the context of areas of priority technologies
Modern technologies for textile industry. A chance for Poland	An announcement of inventorying of technology development directions (descriptions of distinguished technology groups and individual technologies, and identification of a relationship network with technologies in the given area and with technologies from other areas)
The Technology Perspective Kraków-Małopolska 2020 Priority technologies for sustained development of the Podkarpackie Voivodship	Region's knowledge maps, technology index cards and a map of relationships among technologies characteristics of relationships among technologies
Technological development scenarios of the copper ores and accompanying materials of the mining industry in Poland	A review of used technologies (on the basis of literature studies, author's own work, interviews with representatives of sector businesses and outside expert opinions), technology description cards, database of technologies
Technological development scenarios of the bituminous coal mining industry	Technology cards (in a tabular form, filled in on the basis of available scientific and industrial publications and conference reports)
Technological development scenarios of modern metallic, ceramic and composite materials	Analysis of technological directions (on the basis of research and development projects' topics submitted for chosen competitions and topic preferences acquired during a conference organized in the scope of the project), a questionnaire on: material, a manufacturable product and research teams dealing with technologies
The Opolskie Voivodeship as a Region of Sustainable Development - Regional Foresight by 2020	Analysis of technologies (gathering experts' opinions on the technological development stage, opportunities and technological development priorities), utilizing radar charts in order to compare technologies
Advanced industrial and ecological technologies for the country's sustainable development	uniform technology characteristics cards, a base of knowledge of technologies on the website
Zero-emission power management in Poland's sustainable development conditions by 2050	Identification of clusters created by technologies
Food and nutrition in the 21 st century - a vision of Polish food industry development	An assessment of relationships among technologies (a relationships matrix, a dependency tree of technologies, incorporating the technologies' mutual influences and relationships)

Source: own work on the basis of (Czaplicka, 2006; Czaplicka-Kolarz, Klasik, Karbownik, 2010; Dobrzański, 2009; Kozieł & Turek, 2007; Kukla, 2009; Kononiuk & Gudanowska, 2013; Mazurkiewicz & Poteralska, 2011; Michalczyk, 2011; Michalczyk et al., 2007; Narkiewicz & Lubkowski, 2010; Pyka & Czaplicka-Kolarz, 2011; Rogut & Piasecki, 2010; Sobczyk, Łojkowski & Pielaszek, 2009; Szewczyk, 2008; Szpyrka, 2011; Woźniak & Markiewicz, 2010; Woźniak, 2008; Zalewski, 2008; Grupa Gomułka, 2010; Pawlak, 2009; *Analiza kluczowych obszarów...*, 2007; *Foresight technologiczny...*, 2011; *Scenariusze rozwoju technologicznego...*; *Atlas of... Database of...*).



The scope of work in the chosen Polish projects in which executors undertook actions cohesive with the idea of technology mapping was quite diverse, although some recurring elements can be distinguished. Apart from the projects shown in Table 1, in Polish foresight practice there are also detailed descriptions of identified – in a given initiative – technology groups. In some of the analysed projects, technology diagnosis was also based on SWOT analysis, namely distinguishing a technology's strengths and weaknesses, and opportunities and threats for its development, or on the STEEP analysis (or its modification), identifying factors which influence the development of a given technology. In most cases, the conducted analyses did not take into consideration an analysis of connections or the mutual influence among technologies.

The Most Substantial Polish Practices for the Technology Mapping Methodology

In the analysis of the distinguished projects in which practices consistent with technology mapping idea were identified, it can be observed that quite often the technological knowledge accumulation amassed in the scope of these projects constituted each study's value cognitively, but is incoherent in terms of the adopted presentation form. It hinders significantly the process of comparing technologies and requires from the recipient much more detailed reading of the extensive studies to draw any conclusions.

When it comes to relationships among technologies, the initiative Priority technologies for the sustained development of the Podkarpackie Voivodeship is worth noticing, where there was a focus on relationships among leading technologies, from the aspect of their favourable or unfavourable influence on simultaneous development. It was an expert assessment. However, visualization of the collected data was not carried out, leaving the data in the form of a table of averaged expert assessments and in the form of a technology list (Woźniak, 2008). By contrast – Food and nutrition in the 21st century – a vision of the Polish food industry development project, the examination of relationships among technologies was based on cross-impact analysis, incorporating both influences and relationships among technologies (Michalczuk, 2011). The most interesting, constructed in a uniform manner technology description cards are a domain of the Advanced industrial and ecological technologies for the country's sustainable development initiative (*Catalogue of technologies...*). Also, the atlas of technology clusters created in the Technology foresight for industry INSIGHT 2030 project seems to be an interesting idea which, unfortunately, in practice was restricted to the location of Polish centres linked to a given technology (*Atlas of...*). One of the most interesting executions, in the author's opinion, is The Technology Perspective Kraków-



Małopolska 2020. In the scope of the project, region knowledge maps were prepared, as well as technology index cards and a map of connections among technologies. The gathered information on technologies was presented in the form of uniform index cards. The project executors also conducted an analysis of technological potential in clusters and knowledge centres in Małopolska. A knowledge map of Małopolska was drawn up on the basis of information about research and development potential in the region. An analysis was conducted of a list of publications of leading academic centres between the years 2006-2008. A conducted graphic analysis, based on the co-existence of key words in the analysed documents, allowed for the identification of knowledge clusters seen as strengths of the region's knowledge. Ten distinguished technologies of the future were assigned to categories of complementary, supporting and supplementary technologies. An assessment was also done by experts. However, the collected and analysed data was drawn up in the form of a future technologies net (Pawlak, 2009; Grupa Gomułka, 2010).

Recommendations in the Scope of Using the Methodology of Technology Mapping

The conducted review and the critical analysis of the documentation of Polish foresight projects allow for the distinguishing of elements of the diagnosis of the current state of technology which can be held as recommendations in the scope of using the methodology of technology mapping. They are the following:

1. Collecting data on technologies from experts;
2. Arranging the collected data in the form of uniform technology description cards;
3. Compiling a technologies knowledge base in the form of descriptions, tabular compilations and visualizations of chosen technology characteristics;
4. Drawing technology location maps - individual and collective ones;
5. Distinguishing of relationships among chosen technologies on the basis of expert knowledge;
6. Preparing maps representing possibly existing relationships among technologies.

Due to the author's involvement in Technological foresight <<NT FOR Podlaskie 2020>> A regional strategy for a nanotechnology development project, the reflections presented in the article form a basis for the project to proceed in the scope of technology mapping methodology. Within the conducted work, it has been assumed that construction of uniform nanotechnology cards have the highest chances for development in Podlasie, and maps which locate subjects related to chosen technolo-



gies as well as indicate the correlation of those subjects or the technologies' mutual influence.

DISCUSSION AND CONCLUSIONS

The awareness of the fact that recognizing the current condition of technologies whose development determines the choice of key technologies and a given regions' future position is a significant stage, it encourages the author to conclude that further analyses in the scope of creating technology mapping methodology for foresight research as a tool of technology management are imperative.

Technology mapping understood as a diagnosis of the current state of technology is an issue which has still not been well-researched. The conducted analysis intended for a review of operations undertaken only in Polish foresight practice. It would be justified that in future articles foreign experiences be also presented. Moreover, such issues would be worth looking into as the nature of technology or relations among technologies, as well as research on what data decisions are based on the development of a given set of technologies on the level of company, region and country. Analyses and research conducted in that area would significantly enrich the area of technology management and would allow for the generation of operationalised propositions of technology mapping methodology.

Carrying out technology mapping should allow for the construction of a series of maps and visualizations, enriched with descriptive or tabular data on technologies, reflecting the current (at the moment of the analysis) technology state. The aim of such proceedings is providing the fullest possible knowledge about technologies, coming not only directly from technological experts' assessments, but also from the analysis and visualization of information collected during workshops or expert consultations. This approach bases on expert knowledge, but is complemented by a categorization of obtained data and accessible result presentation which allows for the noticing of relationships among technologies which wouldn't be visible in text descriptions. The method seems to be a useful tool for the implementation of operations in the scope of technology management, especially during technology identification and the acquiring of knowledge coming from the development and exploitation of the technologies (learning). Also, the results obtained during the method implementation can constitute the basis for decisions made in the scope of technology selection, thus increasing their validity.

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MAPOWANIE TECHNOLOGII W BADANIACH FORESIGHTOWYCH JAKO INSTRUMENT ZARZĄDZANIA TECHNOLOGIĄ – POLSKIE DOŚWIADCZENIA

Abstrakt

Tło badań. Wiedza o technologiach to jeden z elementów kształtujących rozwój gospodarczy. Równocześnie współczesne technologie cechuje coraz większa złożoność, a ich cykl zastosowania skraca się. Obserwacja i analiza poziomu ich rozwoju staje się swego rodzaju zabezpieczeniem związanych z nimi inwestycji. Logiczną wydaje się potrzeba ustanowienia właściwego sposobu zarządzania technologią i rozwoju metodyki w tym zakresie.

Cele badań. Celem artykułu jest przedstawienie problemu mapowania technologii w zakresie badań foresightowych jako narzędzia zarządzania technologią. Uwagę skupiono głównie na identyfikacji, a następnie analizie i ocenie działań podejmowanych w obrębie diagnozy bieżącego stanu technologii w polskich projektach foresightowych.

Metodyka. Identyfikacja inicjatyw foresightowych podejmujących działania z zakresu diagnozy bieżącego stanu technologii została przeprowadzona poprzez obserwację, analizę dokumentów, analizę i przegląd literatury. Wybór najlepszych spośród zidentyfikowanych praktyk przeprowadzono poprzez ocenę stopnia spełnienia zdefiniowanych przez autorkę kryteriów.

Kluczowe wnioski. Zasadniczym rezultatem przeprowadzonej w artykule analizy jest identyfikacja elementów diagnozy bieżącego stanu technologii, jakie można uznać za rekomendacje w zakresie wykorzystania metodyki mapowania technologii. Obejmują one między innymi przygotowanie kart technologii, lokalizację związanych z technologią zasobów, wizualizację możliwych relacji pomiędzy technologiami.

Słowa kluczowe: mapowanie technologii, foresight, diagnoza bieżącego stanu technologii

