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Maps of Technology Experts Relations and Technology Development Centers Relations as a Part of the Technological Knowledge Base in Foresight Studies

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Abstract: The aim of the paper is to propose a methodology for mapping relations among experts and technology development centers – one of the elements of the technological knowledge base, that might be the result of technology foresight implementation. The author presents the outcomes of the existing published works related to the analysis of technology in foresight studies. Presented conclusions of the review justify the need for technology analysis in relation to the centers and researchers that develop technologies. The article presents both a proposal of the way of information collection and aggregation. An important element of the research is also an aspect of the technologies data presentation in an innovative, graphical form, prepared using tools dedicated to network analysis. The application of proposed solutions has been presented on the example of technology foresight. The research process was supported by literature review, the method of analysis and logical construction and a case study.

Keywords: foresight studies, technology mapping, maps of relations, visualization

1. Introduction

TECHNOLOGY has become a change catalyst in contemporary business, in fact the only one which has been able to stimulate a real change on the market. Entire industry branches, sectors, as well as business functions are transformed by technologies

(Utterback,2002; Antunes,2006; Lee, 2009; Drew, 2009). In the face of strong technology impact upon the market, it has become vital that the dynamic changes which occur in technology are monitored. It has been confirmed by studies conducted by E. Lichtenthaler who indicates that a lack of reaction to a radical techno-logical change usually leads to company bankruptcy (Lichtenthaler, 2007). Estimating the value of technology facilitates indicating the most promising ones. It also allows for identification of a technological niche, owing to which a unique solution may be developed which meets unsatisfied market needs (Pawlak, 2010).

When conducting research on technologies and making a choice among available technologies, it is important to conduct a detailed analysis of the technologies' essential features. Those features ought to encompass an analysis of the life cycle curve of a technology in individual and collective perspectives, an analysis of technological trends in the scope of material properties, technology costs, structure and efficiency, as well as its maturity understood as its development degree (Pretorius, 2000). It is also advised that in the process of selecting a technology attention be paid to uncertainty of commercial and technological success, technology history to date, resources crucial for its development and the degree to which it contributes to realization of the established mission. Moreover, there can exist many relationships among technologies which also ought to be considered. Chosen promising technologies should constitute a link between currently used technologies and the entire organization system (Torrkeli, 2002).

When facing a decision on a choice of technology, a contemporary engineer should possess the knowledge and skills enabling them to conduct a substantive assessment of technical features and characteristics of technologies and products. They must also have a knowledge of management processes, be able to cooperate with specialists from various environments and they must be knowledgeable about current trends in technique and technology development. They also ought to have experience, intuition and ability to use scientific methods in practice, including predictive methods, particularly while making decisions in conditions of uncertainty (Kaźmierczak, 2013). Foresight research may be one of the technology analysis assisting tools. Conducting foresight research capacitates creating a development vision and indicating how to realize them. That process is involved in long-term future of science, technology, economy, the environment and society, realized with the aim of identifying emerging key technologies and stimulating strategic research areas, prognosticating to be the most beneficial in the social or economic aspect (Martin, 1995). What is noticeable in analyses of foresight initiatives in terms of their definitions, assumptions or realizations is the considerable significance which is attached to the technological aspect. That tendency can be confirmed by the number of foresight initiatives with a technological profile. In Poland they constitute more than a half of all finalized or ongoing projects (Nazarko, 2012). In many countries technological foresight encompasses significant activities which constitute help in directing technological development and focusing national resources on technologies which are key for the country (Chen et al, 2012). Foresight utilizes different sources of knowledge such as patents, research and development projects, as well as the Internet, personal contacts and workshops which assemble professionals in a given field so as to sort, order and analyze obtained information, and, as a result, support prioritization of research areas and/or technologies, thus supporting the decision-making process (Antunes et al, 2006).

Technology analysis, similarly to foresight activities, can be connected with diagnostic measures (understanding the current situation), forecasts (pondering about what can happen) and instruction (deciding on what should be done) (Koivisto, et al 2009). In the author's opinion, activities referring to current situation analysis allow for deter-mining the initial position for the remainder of activities. Moreover, it should be noted that the basic requirement of a decision-making process is access to information. Thus, methods which focus on diagnosis of the current state ought to provide as wide a perspective on the research subject as possible, so that the decisions made are as justified as possible. The analysis conducted by the author on current state of technology research methods allowed for detailing several aspects which are paid attention to during a current state of technology analysis. One of the elements of a base of knowledge about technologies gathered while analyzing technologies is the need for investigation into the environment connected with the technology. It applies particularly to research and/or industry units which work on the technology's development and formation. It also applies to the aspect of their present and potential cooperation. In the light of this observation, the main objective of this article has been defined as proposing an original solution to analysis of units and individuals developing chosen technologies, preceded by an analysis of experiences in that area.

2. Background research

Technology observation is now not a choice, but a requirement for survival of a company functioning on a contemporary market. Moreover, observation of technologies' life cycles shows that the mere scientific discovery is not sufficient, because learning the nature of a given phenomenon does not constitute a source of technology (Łunarski, 2009). Having analyzed American and European research, A.S.C. Fernandes indicated that technology is an inseparable part of society (Fernandes, 2012). Evolution of technology is not only a technological process, but also a social one (Klincewicz, 2012). One of the sources of technologies and their development is considered to be the creativity of units functioning in them. The factors which support technology development are also factors present in social relations, namely: striving towards obtaining private benefits and striving towards attaining competitive advantage (Łunarski, 2009). The author's special attention was drawn to persons developing a given technology, described in the publication as experts, and to

companies and academic research centers gathering the experts. For the purposes of the article an analysis has been conducted of chosen research initiatives during the execution of which the aspect of technological development was explored. The focus has been on the observations which referred to the analysis of technology-developing centers and experts. Chosen works have been presented in Table I.

When referring to Polish foresight practice, it can be noted that in foreign experiences more weight is attached to data visualization. Moreover, in many Polish

TABLE I Chosen experiences connected with a diagnosis of the current state of technologies (in relation to development centers and technology experts)

Source	The aspect of development centers and experts on technology
Andersen, Rasmussen, Strange, Haisler 2005; Giesecke, Crehan, 2008	The works concern a foresight project on nanotechnology executed in Den-mark since 2004; the general objective of the project was supplying the knowledge about nanoscience and nanotechnology development in the perspective of the following 20 years as a basis of forming a long-term coherent policy on research, education and innovation in that field; In the project's methodology a knowledge-gaining stage was distinguished whose aim was to indicate the most important “actors” of nanoscience and nanotechnology in Denmark; the search for those “actors” was conducted through collecting information from questionnaires sent to institutions and companies as well as through an analysis of subject publications, with the use of European data-bases.
Yong-Gil Lee, Yong-Il Song 2007	Indicating a survey among field experts as a more effective approach than bibliometric analyses for the reason of utilizing expert knowledge of specific technologies; proposition of the method of technology cluster analysis; research on technology proximity in the field of nanotechnology; proximity is defined as a relation of the number of experts who know both technologies well (from the pair of technologies analyzed at a given moment) to the number of experts who know one of the two technologies well.
Koppe, Lecou, Bröring 2013	Analysis in the field of nanotechnology; the focus was mainly on patent analysis, however, it was noted that research mapping ought to be a significant element from the point of view of searching for suitable partners in technology development and identification of indispensable competencies; It was also found that the possession of competencies in the scope of emerging technological solutions is not always a domain of only one organization or economy.
van der Valk, Chappin, Gijsbers, 2011; van der Valk, Gijsbergs 2010	Utilizing network analysis for research into innovation; three research areas were identified: (1) cooperation networks among organizations, and interpersonal networks, (2) communication networks, (3) structure of research areas and sectors; observed interest in technological cluster analysis, particularly on the basis of analysis of units associated with technological data; highlighted usefulness of that type of analyses for identifying main competitors and potential partners on the market. For monitoring emerging technological innovations, a methodology of innovation networks assessment was developed; visualizations were prepared which presented two types of subjects: projects related to a given research program and their participants; character of project participants was indicated as well as their knowledge areas.

and foreign projects the significance of involvement of field experts in technology analysis is pointed out (Gudanowska, 2013; Gudanowska, 2014).

3. Proposal of methodological procedure

Keeping in mind the analyzed experiences of technology analysis in the view of chosen elements from the technology's environment, the author has developed a procedure of preparing a map of relationships among technology development centers and a map of relationships among experts on analyzed technologies. The procedure is an element of the author's original method of technology mapping in foresight research. It was decided to prepare visualizations for the group of analyzed technologies, crucial for the development of a given sector, region or country. The aim of preparing those visualizations was to enlarge the knowledge base of technologies with the highest potential for development. It was achieved through supplying knowledge not only by making records of centers and persons associated with technology development, but also in the aspect of existing and potential networks of cooperation among research and development institutions, companies producing technologies and experts working on development of the analyzed technologies.

The essential data for map preparation should be collected through a survey among industry experts. When completing the questionnaire, respondents ought to indicate academic centers and manufacturers/producers (understood as companies implementing, applying and developing the given technology). They should also indicate experts who develop the given technology. Surveys are to be conducted separately for each technology, which allows for research among quite a diverse expert group.

On a map of technology development centers, what should be assumed as nodes of the emerging network are all institutions mentioned by the respondents. Connections can be defined as working on the same technology. If there are more common technological areas of interest between two institutions, the connection becomes stronger. Then, with the use of a simple criterion of presence among centers which develop the given technology, a map of relationships is created. The respondents are also provided with the knowledge based on the collected data. The gathered data should be aggregated. Data aggregation ought to encompass preparation of technology sets developed by each center, and then transformation in accordance with the formulas:

$$R_i(A|B) = \sum_{i=1}^{n} r_i(A|B)$$

$$r_i(A|B) = \begin{cases} 1 & \text{when } T_i \in O_A \wedge T_i \in O_B \\ 0 & \text{when } T_i \notin O_A \vee T_i \notin O_B \end{cases} \quad (1)$$

where: $R_i(A|B)$ is a relationship between a chosen pair of centers A and B; $r_i(A|B)$ is a unit relationship between a chosen pair of centers A and B; n is a number of considered technologies; i is a number of a technology, (i = 1, 2, …, n); T_i – a single technology; O_A – a set of technologies developed by center A; O_B – a set of technologies developed by center B.

Similar assumptions have to be made for data preparation for a map of relationships among experts who develop a given technology. Who should become nodes in the expert network are the experts named by the respondents. The mutual relationships among the experts should be preceded by preparation of technology sets developed by each of the experts. The sets ought to be then transformed with the use of the same formula (1), where O_A is a set of technologies developed by expert A and O_B is a set of technologies developed by expert B. The aggregated data should be coded, so that they can be used for visualizations in network analysis software.

4. Case Study

The devised assumptions for creating maps of relationships among technology development centers and maps of relationships among experts who develop the analyzed technologies were utilized in one of foresight projects executed in Poland, namely “NT FOR PODLASKIE 2020”. A regional strategy for nanotechnology development [19], [20]. This publication's author's technology mapping methodology was used in that initiative. In the scope of the methodology, visualizations were created, some of them of experts and technology development centers (Gudanowska, 2014). The technology mapping method complemented activities undertaken in the execution of key technologies method, scenario method and technology roadmaps. During the execution of the project a broad set of technologies was analyzed which were categorized into seven areas: the engineering industry and transportation, wildlife conservation, the clothing industry, the timber industry, medicine, agriculture and food industry, building and construction. Twenty-two key technologies were distinguished and then seven of them were indicated as priority technologies. The key technologies were characterized by being the most attractive and feasible as assessed by industry experts in accordance with adopted criteria. The priority technologies were the ones which should be developed first due to the level of technological readiness and relations with other key technologies. The following priority nanotechnologies were recognized: nanomaterials and nanosurfaces in medical equipment (T20), composite materials for dental fillings (T17), powder technologies in plastic, paint and varnish production (T31), surface nanotechnologies in biomedicine (T21), nanotechnology for cutting instruments and wood processing (T3), nanotechnology for specialized textiles (T24), nanostructuring of metals (T38).

In keeping with the adopted methodology, relationships were determined among centers and experts associated with priority nanotechnologies. Individual centers/experts were adopted as nodes. Sets of technologies were determined whose development is dealt with by a given center/expert. The relationships presented on the maps suggest a presence of a common area of research and development interest on the part of given centers or persons. The weakest links, marked with the lightest color, present interest in technologies from the same area. The stronger ones, marked more

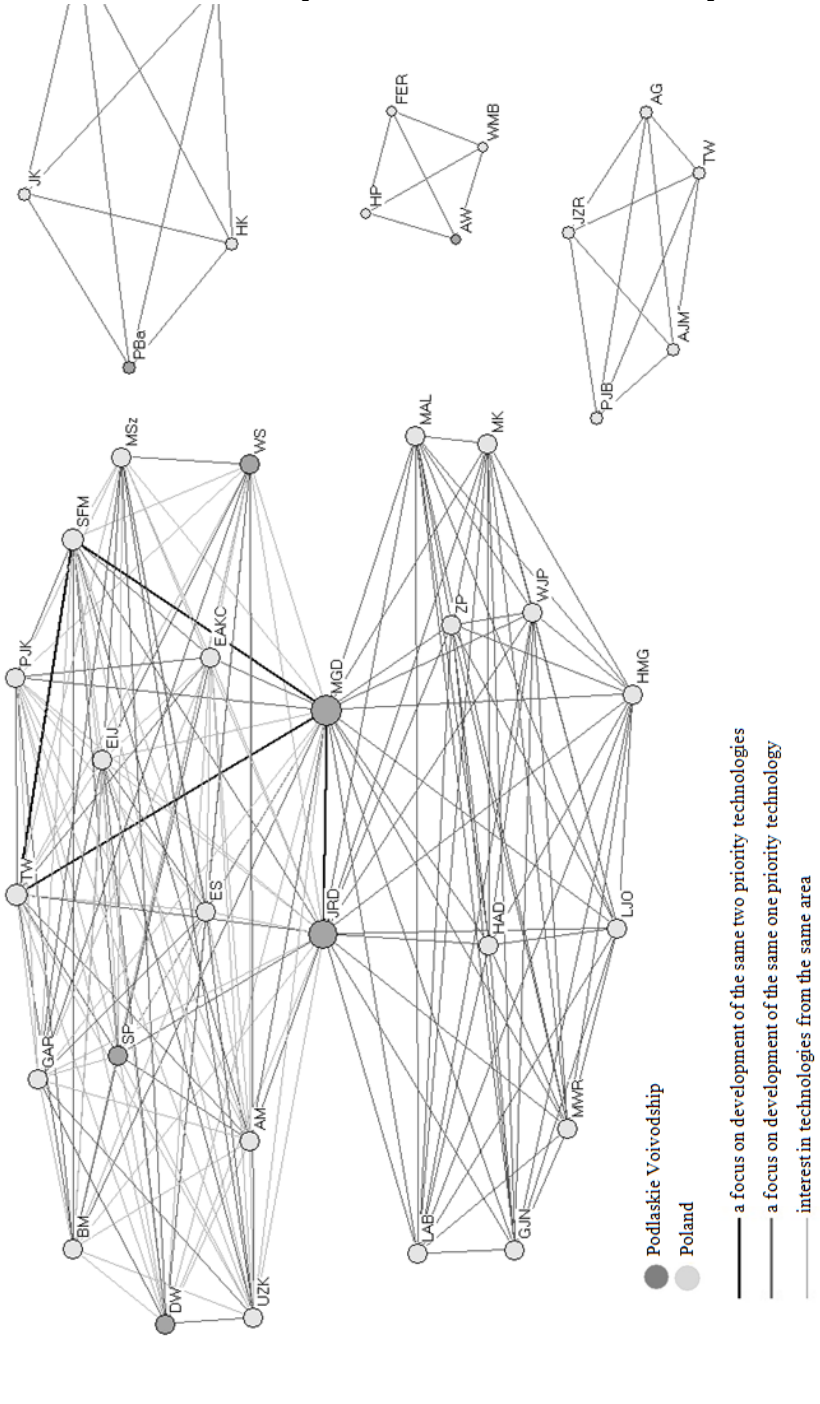

Fig. 1. Example of a map of technology experts relation – “NT FOR PODLASKIE 2020”. A regional strategy for nanotechnology development

(Source: created by the author in Pajek).

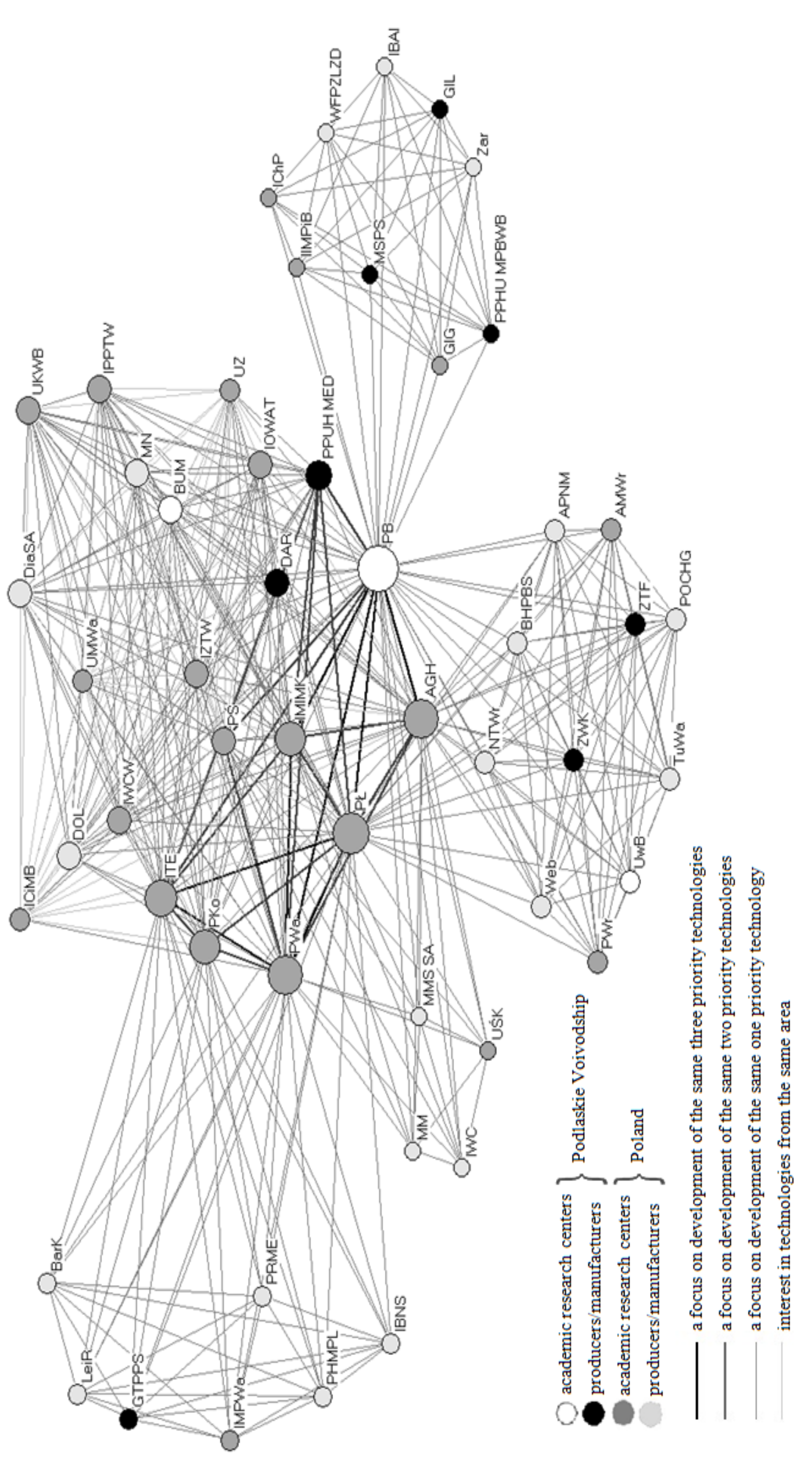

Fig. 2. Example of a map of technology development centers relations –“NT FOR PODLASKIE 2020”. A regional strategy for nanotechnology development

(Source: created by the author in Pajek).

The map of expert relationships (Fig. 1) connected with priority technologies development reflected the existence of common research areas of individual experts. The graph shows a network which was the densest one, which suggests the largest number of links. Three clusters are visible on the peripheries of the network, as well as two experts who cooperate or potentially will cooperate with a substantial number of other subjects. It transpired that the network which covers academic research centers is a dense network, with numerous links, whose heart is formed by centers with the largest number of links. It also transpired that the strongest relationships identified within the academic research centers were among those situated in different parts of the country. The strongest relationship encompassed a focus on development of the same three technologies. In the area of priority nanotechnologies manufacturers/producers, a low-density network was identified, that is, with a small number of links (the maximum number of relationships was more than three times smaller than in the case of academic research centers). In the area of priority nanotechnologies manufacturers/producers, unlinked clusters were identified. The links were also slightly weaker than in the case of academic research centers. A collective list covered both groups of technology development centers and constituted a combination of both networks (Fig. 2). The centers marked by the most entwined nodes (PB, PŁ, AGH) should possess the highest cooperation potential in the scope of priority nanotechnologies development analyzed in the project (Kononiuk et al, 2013).

5. Conclusions

The conducted analyses indicate the importance of creating the broadest possible knowledge base of technologies, in order to aid decisions on the choice of technologies with the highest development potential. One of the indispensable elements to which attention should be paid is the aspect of technology-developing academic and industrial centers. It is there that numerous technological innovations stem from. Another important aspect are technology experts whose creativity constitutes one of the bases of technology development. As important as identification of technologies is the indication of relationships among them in the context of the analyzed set of technologies. That knowledge allows for identification of existing and potential cooperation networks dynamizing development of those technologies. It is noteworthy that those relationships should be examined not only from the angle of academic research centers or companies, but information about possibilities of cooperation between science and industry should be acquired as well.

The paper proposes the conduct, which is part of the method of mapping technology in foresight studies. The conduct allows for identification of technology development centers and technology experts together with relationships understood as existing and potential cooperation networks within the analyzed technologies. An example has been demonstrated of an execution based on the presented procedure, conducted in the scope of one of Polish foresight initiatives. Placement of such analyses in foresight research allows for gathering knowledge which would be difficult to collect by an individual company or researcher, particularly with high specialization level of identified technologies. The form of the presented maps is also noteworthy. It was inspired by network analysis, and using it allowed for a collective presentation of the identified relationships without any loss of visualization legibility.

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