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Technology mapping – an international literature review

Future Industry Platform

Report for the project "Technology mapping in cluster enterprises" implemented by the Future Industry Platform Foundation

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Future Industry Platform

Foreword

We would like to present to you a report that reviews international initiatives in the field of technology mapping. This publication is another study created as part of the work of the think tank established by the Future Industry Platform. This report focuses on technology mapping as a scientific method which, through classification, description and assessment of the potential of companies, allows for determination of the current state of selected technologies.

The choice of this research method was not accidental. The cost-based sources of competitiveness of Polish enterprises are running out, which prompts deeper reflection and the search for new solutions in more developed markets that use new technologies in a much broader aspect to build the potential of enterprises.

During their work, the experts had two primary goals. The first was to identify key competitive advantages. The second one was to develop the basis for developing practical assumptions for the concept of technological competitiveness of the Polish economy. In this case, the focus was on technologies used in the metalworking industry and digital technologies that support its development.

The practical effect of preparing this report was creation of an online tool consisting of two elements: an dictionary of industry technologies and a map of enterprises, which allows for quick search of the location of entities using specific technologies. Its bilingual nature (Polish and English versions) allows for inclusion of Polish enterprises in global value chains.

At the same time, the other aim of the project is to popularize the above-mentioned method by showing the practical possibilities of its application (by using the developed tool). It should be emphasized that this publication is the first of two reports on the subject of technology mapping. The other publication is focused on the topic of operationalization of the methodology for the needs of the metalworking industry and the proposal of tools supporting the implementation of the above-mentioned methods.

I would like to thank the author of both reports, Dr Alicja Gudanowska, for her commitment and knowledge. I hope that both publications, which are the result of joint efforts, will meet with kind interest and positive reception.

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Table of contents

1 Introduction and basic terminology

Technology mapping is one method to determine the current state of a technology by identifying, classifying and collecting data on related elements (such as, for example, components of the technology, examples of its use, related scientific entities, companies or experts developing the technology) and analyzing and visualizing possible links between technologies.

The goal of using the mapping method is to provide the broadest collectible knowledge base on technologies that is useful from the audience's perspective and up-to-date at a given point in time.

The spatial location of units associated with a technology, defined relationships between technologies, or established relationships between selected characteristics can be taken as the subject of a technology map or related elements. According to the commonly accepted idea of a map, technology maps should be supplemented with a legend of the designations used and (optionally) descriptions or tabular summaries of the objects presented on the map[1]. In terms of the technology management process[2,3,] this method is particularly useful in the context of technology identification and selection, as well as during the acquisition of knowledge flowing from their development and operation[4,5].

It is also worth noting that this method has often been used within the framework of studies relating to the future, especially foresight studies. It was on the basis of these that the course of technology mapping methodology was developed and documented[6]. Within the framework of this type of research, this method enables the categorization and classification of technologies and is used, among other things, to review the object of analysis and define its boundaries[7,8]. Taking into account the essence of the field of foresight

1 A. E. Gudanowska, *Metodyka mapowania technologii w badaniach foresight*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2021, DOI: 10.24427/978-83-67185-01-1, https://pb.edu.pl/oficyna-wydawnicza/wp-content/uploads/sites/4/2022/01/Metodyka-mapowania-technologii-w-badaniach-foresight2.pdf

2 R. Phaal, C. J. P. Farrukh, D. R. Probert, *Technology management process assessment: a case study*, "International Journal of Operations & Production Management" 2001, vol. 21, no. 8.

3 D. Cetindamar, R. Phaal, D. Probert, *Understanding technology management as a dynamic capability: A framework for technology management activities*, "Technovation" 2009, no. 29.

4 A. E. Gudanowska, *Metodyka mapowania technologii w badaniach foresight*… op. cit.

5 A. Gudanowska, *Istota współczesnych technologii w kontekście procesów zarządzania technologią i foresightu technologicznego*, „Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie” 2015, no. 83, pp. 195–205.

6 A. E. Gudanowska, *Metodyka mapowania technologii w badaniach foresight*… op. cit.

7 P. D. Andersen, B. H. Jorgensen, L. Lading., B. Rasmussen, *Sensor foresight – technology and market*, "Technovation," vol. 24, 2004.

8 B. Rasmussen, M. Borup, K. Borch, P. D. Andersen, *Prospective technology studies with a life cycle perspective*, “International Journal of Technology, Policy and Management”, vol. 5, no. 3, 2005.

research in the context of the development of the technology mapping methodology, in this report an important source of knowledge will be the items documenting the initiatives carried out within the framework of such research both in Poland and around the world.

It is also important from the perspective of this report to distinguish the concept of technology mapping from the *technology roadmapping* (TRM) method, with which technology mapping is quite often equated, especially in the Polish literature. The main difference between the two methods is the time[9]. In the case of mapping, it is the specific point at which we review the technology. While it is possible (and even recommended) that this review be updated, especially in the case of creating a tool intended to facilitate the use of the knowledge accumulated in the technology database for its recipients, it is a clearly marked point in time. In contrast, in the case of the *technology roadmapping* method, the result of the implementation is to be visualizations relating to the timeline, often providing information on five areas: market, products, technology, process and people. They present different layers with different levels of detail[10], rather than a detailed overview of the current state of existing technologies[11]. Although realizations of the TRM method are quite diverse approaches, the end result is an ordering or presentation of changes in scientific research directions and technologies in their broad context in relation to the timeline[12].

Various methods and ideas related to the study of the state and development of technology have been of interest to researchers for a long time. Analyses of the phase of the technology life cycle, factors influencing its development, possible directions of development or other aspects are interlocking areas. Often these are derivatives of older and, at the same time, still being developed in parallel approaches[13]. The technology mapping method has been implemented in different ways over the years in a variety of initiatives. In the literature, one can also find studies not explicitly defined as technology mapping, but in line with its idea. The use of the method is intended to help understand the complexity of the technologies being analyzed, and the results obtained through its implementation can be a relevant and legitimate argument when making technology selection decisions[14, 15].

Technology mapping, therefore, should be, and often has been, a natural stage of research and initiatives aimed at highlighting existing structures and linkages in

9 A. E. Gudanowska, Mapowanie a foresight. *Wybrane aspekty metodologiczne jednego ze współczesnych nurtów badawczych w naukach o zarządzaniu*, „Współczesne Zarządzanie" 2012, no. 4, pp. 103–111.

10 G. Muller, *Roadmapping*, Philips Embedded Systems Institute, 2008, pp. 1–2.

11 *Foresight Vehicle Technology Roadmap – Technology and Research Directions for Future Road Vehicles*, Society of Motor Manufacturers and Traders Ltd, London 2004.

12 K. Cuhls, R. Johnston, (2008), *Corporate Foresight*, [in:] Cagnin C. (ed.), Keenan M. (ed.), Johnston R. (ed.), Scapolo F. (ed.), Barre R. (ed.), *Future-Oriented Technology Analysis*, Springer, 2008, p. 111.

13 K. A. Kujawa, K. Paetzold, *External Technology Searching Methods – A Literature Review*, Proceedings of the 22nd International Conference on Engineering Design (ICED19), Delft, The Netherlands, August 5–8, 2019, pp. 2259–2267.

14 A. Gudanowska, *Technology mapping in foresight studies as a tool of technology management. Polish experience*, "International Journal of Contemporary Management" 2013, vol. 12, no. 4, pp. 61–72.

15 A. Gudanowska, *Technology mapping in foresight studies as a tool of technology management. Polish experience*, "International Journal of Contemporary Management" 2013, vol. 12, no. 4, pp. 61–72.

the aspect of technology analysis, or the flows of information or resources in the structure of the entire network of technologies used in a given area, company or their group[16].

The purpose of this report is to provide:

- knowledge useful in developing a technology mapping methodology for metal cluster enterprises,
- assistance in developing a research tool for automated data collection (enterprise cards),
- assistance in developing a database of companies and related technologies,
- assistance with data visualization representing selected technologies,
- assistance in drafting technology descriptions.

With these goals in mind, the literature review focused both on the methodologies adopted in conducting technology mapping in described research cases, as well as on the elements identified in the individual studies that are relevant from the perspective of identifying and gathering knowledge, both about the technology and its developers, and also entities using specific technological solutions.

16 *A. E. Gudanowska, Metodyka mapowania technologii w badaniach foresight* … op. cit.

2 Literature review on the implementation of elements of the technology mapping methodology

2.1. National experiences

One of the research initiatives in the stream of foresight studies carried out in Poland that is worth noting in the context of technology mapping is *Foresight technologiczny w zakresie materiałów polimerowych* (*The Polymer Materials Technology Foresight Project*). As part of one of the ongoing research phases, the implementers conducted a technological review. Expert groups were responsible for gathering knowledge in this process. They reviewed polymer materials and composites, as well as classified technologies according to their division into declining technologies (rejected in further work), mature technologies (partially rejected in further work due to the prevalence of use), prototype technologies and future technologies. The basis for classification was environmental validity, economic validity, creativity and feasibility aspects. In addition to expert knowledge, the data sources used included scientific publications, industry publications and conference reports on polymer materials. The implementers paid attention to the personnel potential of Polish scientific and research institutions, authorship of patents, licenses and implementations, and inventoried companies producing and/or processing polymeric materials. Also important during the work were the strengths and weaknesses of the technologies, as well as the opportunities and threats affecting their development[17,18,19].

From the perspective of technology mapping, it can be considered important to emphasize the importance of inventoried enterprises related to a given technology. On the other hand, from the aspect of technology mapping, the environmental impact, economic implications of technology development, records of patents and implementations and scientific and industrial work, as well as the identification of determinants and barriers to technology development can be considered important elements.

17 H. Rydarowski, K. Czaplicka, *Wybrane scenariusze rozwoju technologicznego materiałów polimerowych* [electronic document]. Access: http://science24.com/paper/14851 [Accessed: 07.07.2023].

18 *Foresight technologiczny w zakresie materiałów polimerowych* [electronic document]. Access: www.foresightpolimerowy.pl/main.php?dynxml0=projekt.xml [Accessed: 23.02.2012].

19 *Foresight technologiczny w zakresie materiałów polimerowych*, spotkanie paneli roboczych M5 i M6, 2006, [electronic document]. Access: www.foresightpolimerowy.pl/upload/M5%20i%20M6.pps [Accessed: 24.02.2012].

Another study that can inspire technology mapping is a project in the nature of a foresight study *Scenariusze rozwoju technologicznego przemysłu wydobywczego węgla kamiennego (Scenarios for Technological Development of the Coal Mining Industry)*, which conducted an assessment of the technological state of the country's coal mining industry, reviewing, among other things, the state of technologies used to date. As part of the undertaken work, a tool referred to as a technology card was developed. The tool, in the form of a table, was based on scientific and industry publications and conference materials. The card included such characteristics as a basic description of the technology, distinguishing features of the technology, visualizations and sketches of the technology, advantages and disadvantages of the technological solution from the perspective of efficiency, safety and environmental protection, environmental impact, necessary equipment related to the use of the technology, basic technical and/or organizational parameters related to the technology, and expected production effects. In addition to the technology card, for the purpose of further work, an expert assessment of the innovativeness of the technology was carried out using, among other things, an assessment of the current level of technology development[20,21,22]. Figure 1. shows one of the technology cards developed as part of the research initiative.

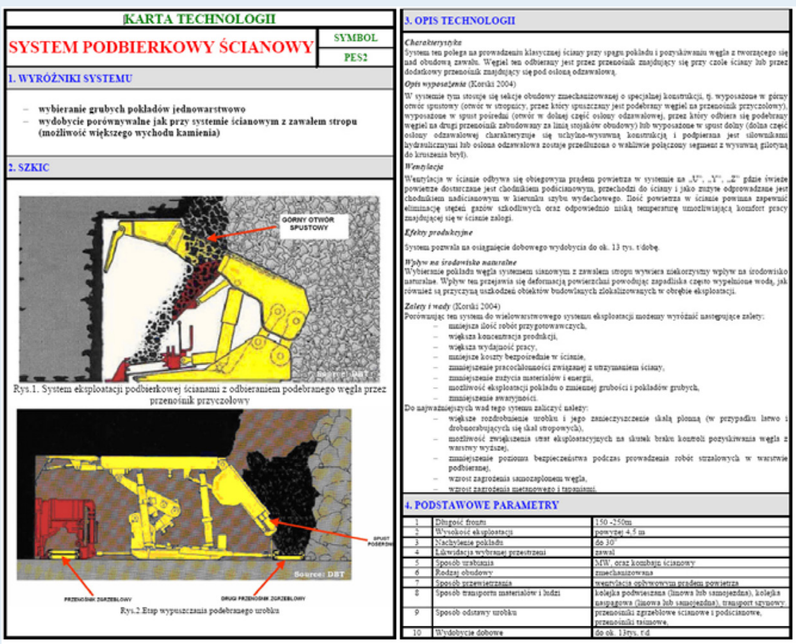


Fig. 1. Example of technology card – project *Scenariusze rozwoju technologicznego przemysłu wydobywczego węgla kamiennego*

Source: Presentation *Scenariusze rozwoju technologicznego przemysłu wydobywczego węgla kamiennego* [electronic document]. Access: www.nauka.gov.pl/fileadmin/user_upload/42/14/42145/foresightweglowy_mg.ppt, [Accessed: 24.02.2012].

20 J. Dubinski, M. Turek, J. Dubinski, *Istota i zakres scenariuszy rozwoju technologicznego przemysłu wydobywczego węgla kamiennego* [electronic document]. Access: www.foresightweglowy.pl/prezentacje/2007_02.ppt, [Accessed: 24.02.2012].

21 Presentation *Scenariusze rozwoju technologicznego przemysłu wydobywczego węgla kamiennego* [electronic document]. Access: www.nauka.gov.pl/fileadmin/user_upload/42/14/42145/foresightweglowy_mg.ppt, [Accessed: 24.02.2012].

22 A. Koziel, M. Turek, *Scenariusze rozwoju technologicznego przemysłu wydobywczego węgla kamiennego*, 2007 [electronic document]. Access: www.wnp.pl/artykuly/scenariusze-rozwoju-technologicznego-przemyslu-wydobywczego-wegla-kamiennego,4147.html [Accessed: 10.07.2023].

As elements relevant from the perspective of the technology mapping methodology, we can distinguish here the assessment of the level of development of a technology, the assessment of its innovativeness and the creation of a tool for collecting knowledge about technologies – a technology card. Attention should be paid to the elements constituting its scope, such as description of the technology and its basic parameters, related visualizations illustrating its operating principles, advantages and disadvantages (including differentiators) of a given solution, environmental impact, effects of production, and necessary equipment of the unit developing/using the technology.

Another study requiring attention from the perspective of technology mapping methodology was the foresight study *Scenariusze rozwoju technologii nowoczesnych materiałów metalicznych, ceramicznych i kompozytowych (Scenarios for the development of technologies for modern metallic, ceramic and composite materials)*. The research initiative analyzed technological directions relevant to the project perspective. Technologies were extracted from the research and development project topics submitted in the competition proceedings, as well as indications from field specialists gathered at a conference organized by the project. Subsequently, a summary of technological directions was created, describing them from two perspectives: material (paying attention to, among other things, properties, dimensionality, size, application) and product (focusing on description, advantages, level of development). Research teams for technologies[23,24] were also highlighted.

As elements relevant from the perspective of the technology mapping methodology, it is important to point out here the conducted record of specialists dealing with the technologies in question and the creation of a tool for recording data on technologies. Considering the planned technology card, it is worth noting the basic descriptions of the technology, the advantages of its use, the determination of the level of development of the technology, as well as the materials used and the products created as a result of its use.

Another initiative worth noting is the foresight project *Scenariusze rozwoju technologicznego przemysłu wydobywczego rud miedzi i surowców towarzyszących w Polsce (Scenarios of technological development of the copper ore and associated raw materials mining industry in Poland)*. A review of technologies used in the copper ore and associated raw materials mining industry was carried out by, among other things: analyzing the literature, the implementers' own work, selected groups of technologies used by

23 D. Kukla, *Pozycjonowanie technologii będących przedmiotem badań w projekcie Foremat*, Rozdział raportu projektu FOREMAT: „Scenariusze rozwoju materiałów metalicznych, ceramicznych i kompozytowych", [electronic document]. Access: www.nanonet.pl [Accessed: 24.02.2012].

24 J. Sobczyk, W. Łojkowski, R. Pielaszek, Metodyka Projektu FOREMAT *„Scenariusze rozwoju zaawansowanych materiałów metalicznych, ceramicznych i kompozytowych*", Rozdział raportu projektu FOREMAT: „Scenariusze rozwoju materiałów metalicznych, ceramicznych i kompozytowych" [electronic document]. Access: www.nanonet.pl [Accessed: 24.02.2012].

major industry companies, and using the results of external expertise and interviews with industry representatives. A database of technologies (with their description contained in cards) was created, which, however, were not comprehensively standardized, which was probably imposed by the specifics of the described group of technologies.

Among other things, the descriptions included in the cards focused on[25]:

- basic description,
- type of technology,
- basic technical elements,
- expert assessment of technology innovation (divided into conservative, developmental or innovative),
- conditions related to the use of technology,
- technology differentiators.

The creation of a technology knowledge base and a technology description card can be highlighted as elements important from the perspective of technology mapping methodology. From the perspective of the technology card, it is worth highlighting the baseline characteristics of the technology, the assessment of innovation, its benefits/advantages in the context of other solutions in the form of differentiators, and the determinants of technology development.

In turn, project *Foresight wiodących technologii kształtowania własności powierzchni materiałów inżynierskich i biomedycznych* (*The Foresight project of leading technologies for shaping the surface properties of engineering and biomedical materials)* included the creation of a book of analyzed technologies as a knowledge base dedicated to pro-innovation entrepreneurs. The cards were planned to include such information as: publications on the solutions in question, entities developing and/or implementing the analyzed technologies, areas of application, basic descriptions of the technologies, basic descriptions of the technological process flows, advantages and disadvantages of the solutions in question, assessment of the impact of the technologies on various areas.

The name of technology mapping appears in the project as a term for the stage of analyzing the current situation of technologies. Knowledge for technology mapping was provided by industry experts[26, 27, 28, 29].

25 Baza technologii w ramach projektu: *Scenariusze rozwoju technologicznego przemysłu wydobywczego rud miedzi i surowców towarzyszących w Polsce*. Access: foresight.cuprum.wroc.pl/technologyList.php [Accessed: 24.02.2012].

26 L. A. Dobrzański, *Kształtowanie struktury i własności powierzchni materiałów inżynierskich i biomedycznych*, Wyd. International OCSCO World Press, Gliwice 2009, p. 164.

27 A. Dobrzańska-Danikiewicz, presentation *Cele i metodologia Projektu FORSURF nt. Foresight wiodących technologii kształtowania własności powierzchni materiałów inżynierskich i biomedycznych*, 2nd Workshop on Foresight of surface properties formation leading Technologies of engineering materials and biomaterials, Białka Tatrzańska, 2009.

28 A. Dobrzańska-Danikiewicz, *Komputerowo wspomagane metody foresightowe w zastosowaniu do inżynierii powierzchni*, „Czasopismo techniczne. Mechanika” 2011, vol. 4, no. 7.

29 A. Dobrzańska-Danikiewicz, *Metodologia komputerowo zintegrowanego prognozowania rozwoju inżynierii powierzchni materiałów*, Wyd. International OCSCO World Press, Gliwice 2012.

From the perspective of technology mapping methodology, it is worth noting here: emphasizing the need to record entities related to the creation and development of technologies and technology publications, indicating areas of application of technological data, indicating advantages and disadvantages, supplementing general descriptions of technologies with a description of the technological process flow, and assessing the impact of technologies.

As part of *Foresight priorytetowych, innowacyjnych technologii na rzecz automatyki, robotyki i techniki pomiarowe (The Foresight of priority innovative technologies for automation, robotics and measurement technology),* an assessment of the regions' potential for developing technologies of interest to the project implementers was carried out. On the basis of literature analysis, study tours, own work in the framework of working meetings and expert knowledge, lists and textual compilations were developed covering entities related to the analyzed group of technologies and directions of research and projects, including: manufacturers, integrators and users of technologies, technology parks and clusters, as well as scientific and research and development centers, and potential recipients of solutions in the analyzed technology industry were identified. It also addresses the aspect of possible interrelationships between technologies in terms of their level of influence, both in terms of a single technology and their entire group[30, 31].

From the perspective of this report, in the context of the creation of a technology mapping methodology, attention can be drawn to the project's inventory of centers associated with the creation and development of technologies and those that are potential recipients of the production effects associated with a given group of technologies. Also important here seems to be the identification of the directions of research work undertaken related to technologies, as well as the fact, noted by the implementers, of the existence of possible connections and impacts of technologies on each other.

In the *Foresight w zakresie priorytetowych i innowacyjnych technologii zagospodarowywania odpadów pochodzących z górnictwa węgla kamiennego* (*Foresight study on priority and innovative technologies for coal mining waste management),* as part of the diagnosis of the current state of development of prevalent and innovative technologies, a description of individual solutions (from among the group of technologies analyzed) was carried out in the form of technology cards and the level of their innovation was assessed.

30 Szewczyk (ed.), *Foresight priorytetowych, innowacyjnych technologii na rzecz automatyki, robotyki i techniki pomiarowej*. Metodologia, analizy i diagnoza stanu obecnego, Przemysłowy Instytut Automatyki i Pomiarów, Warszawa 2008.

31 Szewczyk (ed.), *Foresight priorytetowych, innowacyjnych technologii na rzecz automatyki, robotyki i techniki pomiarowej. Krzyżowa analiza wpływów, scenariusze rozwoju, priorytetowe technologie*, Przemysłowy Instytut Automatyki i Pomiarów, Warszawa 2010.

Such aspects were taken into account as[32]:

- technological level advancement,
- effectiveness of the technology,
- versatility of the technology,
- impact of the technology on the environment,
- health and safety aspect.

From the perspective of this project and the technology mapping methodology, it is worth noting the assessment of the level of development of the technology, its impact on the environment, and the conditions associated with the development and use of the technology.

The foresight project *Zaawansowane technologie przemysłowe i ekologiczne dla zrównoważonego rozwoju kraju (Advanced Industrial and Environmental Technologies for Sustainable National Development)* included, among other things, a diagnosis of the current state of technology.

Within the framework of five thematic areas selected in the project, based on expert knowledge and analysis of research achievements of leading world, European and Polish scientific centers and technological achievements, a list of technologies was generated. In addition to being assigned to the mentioned areas, they were subjected to classification by indicating their membership in the group of incremental or emerging technologies. Based on the knowledge of experts, technology characterization cards (in the form of an electronic form) were developed , which were then published in the form of a card database on the project website.

Attention was paid here to such characteristics as the stage of development of the technology, scope and purpose of application, alternative solutions, general description of the technological solution, areas of current and potential application, necessary human capital, degree of interdisciplinarity, possible effects of use.

Figure 2. shows a sample card. It is also worth noting that in the framework of further project work, during the implementation of the *technology roadmapping* method, attention was focused on the aspects of assessing the economic, environmental and social effects associated with the development of technologies, the level of interdisciplinarity of solutions, as well as the key qualifications and competencies associated with the creation and use of the analyzed group of technologies[33,34].

32 J. Szpyrka, Priorytetowe i innowacyjne technologie zagospodarowania odpadów pochodzących z górnictwa węgla kamiennego, Gliwice 2011.

33 Metodologia foresightu technologicznego w obszarze zrównoważonego rozwoju, Collective work, ITeE-PIB, Radom 2011.

34 A. Mazurkiewicz, B. Poteralska, Zaawansowane technologie przemysłowe i ekologiczne dla zrównoważonego rozwoju kraju, Wydawnictwo Naukowe Instytutu Technologii Eksploatacji – Państwowego Instytutu Badawczego, Radom 2011, p. 13.

From the perspective of the technology mapping methodology, it is worth noting the following elements of the implementation of the described project: classification of the technologies described in the technology charters, the need to create a publicly available knowledge base on the basis of the technology description cards, determining the stage of development of the technology, making a general description of the technology, determining the scope, purpose and areas of its application, indicating technological alternatives, the impact of the technological solution on the broader environment, as well as paying attention to the necessary competencies and qualifications for the development and application of the technology.

The initiative *LORIS Wizja. Regionalny foresight technologiczny (LORIS Vision. Regional technological foresight)* assumed, among other things, an analysis of the current technological profile of the Łódź region. The focus was on research and analytical work in the field of priority technologies for the region from the perspective of the project. Publications from the five years preceding the project were reviewed, as well as selected national and global databases relating to technological solutions and research and development work. Links between technologies were also presented in the form of a technology network based on expert knowledge and the analytical work carried out, relying (among other things) on the developed sustainability index and the results of the one-factor and two-factor analysis[35,36,37].

From the perspective of technology mapping, it is worth noting the following activities undertaken as part of the initiative: emphasizing the importance of research and R&D work and its impact on the identification of future technological directions, as well as highlighting the possibility of links between technologies and attempting to visualize them in the form of networks.

Województwo Opolskie Regionem Zrównoważonego Rozwoju – Foresight Regionalny do 2020 r. (Opolskie Voivodeship as a Region of Sustainable Development – Regional Foresight to 2020) is a research project that analyzed technologies on the basis of experts' opinions with regard to the state of advancement, relevance of the development of a solution and its development opportunities. The implementers aimed to determine the demand for selected technologies in a certain time perspective. The project paid special attention to: ecological, social and economic costs, benefits in the analogous three approaches, and barriers associated with the implementation of given technological solutions in the region due to their nature and level. Each technological area was also described[38].

35 L. Michalczuk, D. Goszczyńska, W. Ambroziak, J. Michalak, B. Michalczuk, I. Sowik, J. Chociłowska-Chołuj, J. Brzozowska-Michalak, *LORIS Wizja. Regionalny foresight technologiczny. Inwentaryzacja istniejących zasobów wiedzy o województwie łódzkim i technologiach istotnych z punktu widzenia rozwoju gospodarki regionu*, Skierniewice 2007.

36 *LORIS Wizja. Regionalny foresight technologiczny. Gdzie jesteśmy i dokąd zmierzamy, czyli jak określić kierunki rozwoju technologicznego województwa łódzkiego*, Przewodnik metodologiczny przygotowany pod kierunkiem A. Rogut i B. Piaseckiego, Łódź 2007.

37 M. Zalewski (ed.), *Perspektywy zrównoważonego rozwoju regionu łódzkiego: szanse i zagrożenia,* SWSPiZ, Łódź 2008.

38 Report *Analiza kluczowych obszarów badawczych. Województwo Opolskie Regionem Zrównoważonego Rozwoju – Foresight Regionalny do 2020 r.*, konsorcjum: RESOURCE Pracownia Badań i Rozwoju, PPNT, [electronic document]. Access: www.foresight.po.opole.pl/pliki/Analiza_kluczowych_obszarow_badawczych.pdf [Accessed: 24/02/2012].

INNOWACYJNA GOSPODARKA NARODOWA STRATEGIA SPÓJNOŚCI | Zaawansowane Technologie | UNIA EUROPEJSKA EUROPEJSKI FUNDUSZ ROZWOJU REGIONALNEGO

Zaawansowane technologie przemysłowe i ekologiczne dla zrównoważonego rozwoju kraju

OBSZAR TEMATYCZNY:	**Specjalizowana aparatura badawcza i testowa**
NAZWA TECHNOLOGII:	**Modułowe komory klimatyczne do specjalizowanych zastosowań**
FAZA ROZWOJU TECHNOLOGII:	funkcjonująca na rynku
ZAKRES STOSOWANIA:	możliwa do zastosowania na skalę jednostkową możliwa do zastosowania na skalę masową
TECHNOLOGIE ALTERNATYWNE:	specjalizowane pomieszczenia o ściśle regulawanych charakterykach klimatycznych oraz pzoimie czystości (np. cleaning room
OPIS TECHNOLOGII:	Cel stosowania technologii: Komory do badań i charakterystyki środowiska procesowego są przeznaczone zarówno do modelowanie środowiska procesowego, w którym dopiero są badane materiały, jak również do wytworzenia środowiska, które jest podmiotem badań. Ogólna charakterystyka technologii: Komory do badań i charakterystyki środowiska procesowego obejmują: 1. Stanowiska badawcze służące do wytworzenia środowiska, które jest podmiotem badań; 2. Stanowiska przeznaczone do modelowanie środowiska procesowego, w którym dopiero są badane materiały lub obiekty techniczne. Komory służące do wytworzenia środowiska są przede wszystkim wykorzystywane w badaniach właściwości fizycznych i chemicznych atmosfer o precyzyjnie skomponowanym składzie. Komory przeznaczone do modelowanie środowiska procesowego, w którym są badane materiały lub obiekty techniczne obejmują: komory fitotronowe stosowane do hodowli roślin, zwierząt laboratoryjnych, grzybów, glonów, komory klimatyczne, komory solne przeznaczone do testów korozyjnych w mgle solnej
OBSZARY AKTUALNYCH ZASTOSOWAŃ:	**Rolnictwo, leśnictwo, łowiectwo i rybactwo** Przykładowe zastosowanie: 1. Badania hodowli roślin w stymulowanych i ściśle kontrolowanych warunkach klimatycznych 2. Specjalizowane badania mikrobilogiczne 3. Badania wpływu parametrów klimatu na glebę, rozwój mikroorganizmów wglebie **Górnictwo i wydobywanie** Przykładowe zastosowanie: Badania wytrzymałości obiektów technicznych w warunkach kontrolowanego wybuchu gazów występujących w kopalniach węgla kamiennego **Przetwórstwo przemysłowe** Przykładowe zastosowanie: Badania eksploatacyjne, normatywne i atestacyjne w energetyce, meblarstwie, elektronice **Budownictwo** Przykładowe zastosowanie: Badania atestacyjne i dopuszczające (certyfikacyjne) w budownictwie, np.: badania karbonatyzacji betonu **Działalność profesjonalna, naukowa i techniczna** Przykładowe zastosowanie: Badania tribologiczne w precyzyjnie kontrolowanych warunkach klimatycznych,w szczególności w zaprogramowanych temperaturach i wilgotnościach; badania odporności na korozję podzespołów maszyn w warunkach zwiększonej wilgotności
PROGNOZOWANY KIERUNEK ROZWOJU:	Prognoza 2015: 1. Rozwój systemów kontrolno-pomiarowych w celu zapewniania odpowiedniej dynamiki zmian charakterystyk środowiska klimatycznego; 2. Zastosowanie nowych materiałów konstrukcyjnych i funkcjonalnych do budowy komór; 3. Zwiększenie zakresów parametrów regulowanych (sterowanych), np. temperatury, składu atmosfery 4. Zastosowanie technologii teleinformatycznych do monitorowania długi testów badawczych (wielomiesięcznych) 5. Zastosowanie sterowników PLC i mikrokontrolerów do uzyskania wielofunkcyjności (poprzez rekonfigurację torów pomiarowych i sterujących w wyniku zmian oprogramowania). Prognoza 2020: 1. Hybrydyzacja komór - wykorzystanie konstrukcji dla różnych potrzeb badawczych; 2. Rozwój oprzyrządowania dodatkowego; 3. Zmniejszenie energochłonności.
STOPIEŃ INTERDYSCYPLINARNOŚCI ROZWIĄZANIA:	średni w zakresie dziedzin: elektroniki, automatyki, metrologii, informatyki
POTENCJALNE EFEKTY WYKORZYSTANIA TECHNOLOGII:	Ekologiczne: **Zużycie surowców naturalnych (w tym wody)** - efekt pozytywny **Zużycie źródeł energii** - efekt neutralny **Powtórne wykorzystanie produktów i materiałów w procesie wytwarzania (w tym odpadów przemysłowych)** - efekt pozytywny **Możliwość precyzyjnego kontrolowania oddziaływania ewentualnych substancji szkodliwych badanych w komorach na środowisko naturalne poza komorą** - efekt pozytywny Ekonomiczne: **Koszty prowadzenia prac badawczych i rozwojowych** - efekt pozytywny **Koszty funkcjonowania przedsiębiorstw** - efekt pozytywny **Poziom konkurencyjności przedsiębiorstw** - efekt pozytywny **Poziom przedsiębiorczości w sektorze high-tech** - efekt pozytywny **Poziom zysków** - efekt pozytywny

Fig. 2. Example of technology card – project Zaawansowane technologie przemysłowe i ekologiczne dla zrównoważonego rozwoju kraju

Source: *Metodologia foresightu technologicznego w obszarze zrównoważonego rozwoju*, Collective work, ITeE – PIB, Radom 2011, p. 49.

From the perspective of technology mapping, this project should pay attention to assessing the level of development of the technology, making a basic description of the technology, determining its impact on the environment in terms of benefits, costs and barriers that its development or implementation may involve.

Priorytetowe technologie dla zrównoważonego rozwoju województwa podkarpackiego project (*The Priority Technologies for the Sustainable Development of the Subcarpathian Voivodeship)* involved an analysis of the relationship between technologies. As part of its implementation, an expert assessment was carried out in the form of a matrix of assessments and a list of technologies affecting the development of others within the industry, which made it possible to identify opportunities for the coexistence of technologies and limitations preventing or inhibiting their mutual use. Further work also included the development of paths to the implementation of a given technology, which captured aspects such as the necessary activities, the necessary financing and the identification of organizations responsible for the implementation of development activities[39,40].

For the technology mapping methodology, it is important here to pay attention to the occurrence of links between the development of individual technologies, barriers to technology development, and the aspect of financing and entities responsible for technology development.

The foresight study *Perspektywa Technologiczna Kraków-Małopolska 2020* (*Technological Perspective Kraków–Malopolska 2020)* included, among other things, the creation of a knowledge map of the region created on the basis of an analysis of regional publications of leading scientific centers. The map had the character of a bibliometric map indicating the co–occurrence of keywords characterizing the analyzed documents. Through its compilation, the strengths of the knowledge accumulated in the region were identified while indicating those areas that have the potential to build research or implementation teams. The project also developed a tool for gathering knowledge about a selected group of technologies, called technology fiches. These contained such characteristics as indicating its area of application, indicating the product or final service, and importance for the region. The project also created a map of relations between technologies identified as future–oriented. Relationships could take the form of complementary, supporting or improving/complementary solutions. Further work

39 L. Woźniak (ed.), *Końcowy raport z badań FORESIGHT Priorytetowe technologie dla zrównoważonego rozwoju województwa podkarpackiego*, Oficyna wydawnicza Politechniki Rzeszowskiej, Rzeszów 2008.

40 *Końcowy Raport z Badań Foresight Priorytetowe Technologie dla Zrównoważonego Rozwoju Województwa Podkarpackiego*, Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 2008, p. 330 [electronic document]. Access: www.prz.edu.pl/foresight/index.php?option=com_docman&task=cat_view&gid=4&Itemid=21 [Accessed :24/02/2012].

including the identification of technology directions also paid attention to the determination of technology readiness, technology development goals and focused on the entities responsible for technology implementation[41,42].

From the perspective of operationalizing the technology mapping methodology, it is important to note the aspect of technology dependence taken into account by the project implementers, the essence of monitoring knowledge related to technologies by determining its technological readiness, analysis of publications, creation of a tool for collecting knowledge about technologies containing information relating to areas of technology application, production effects of technology use and benefits that technology brings to the region, as well as the essence of monitoring entities related to the development or implementation of technologies.

The implementers of the projects *Nowoczesne technologie dla włókiennictwa. Szansa dla Polski* and *Foresight regionalny województwa zachodniopomorskiego* (*Modern Technologies for Textiles. Opportunity for Poland* and *Regional Foresight of the West Pomeranian Voivodeship),* while analyzing the directions of technology development, paid special attention to gathering the knowledge about technologies through bibliometric and patent analyses. The former project also pointed out the importance of analyzing links occurring between technologies[43, 44].

Thus, given the methodology of technology mapping, it can be considered important to look at technologies as a certain interrelated system, and to emphasize the importance of records of publications and patents.

Żywność i żywienie w XXI wieku – wizja rozwoju polskiego sektora spożywczego (The Food and Nutrition in the 21st Century – a vision for the development of Poland's food sector) initiative assessed the probable period of implementation of the technologies identified as critical within the framework of the project, determined their level of development, their competitive position, and identified the links between technologies. A cross–impact analysis was used to identify the links, and the technologies were finally divided in terms of impact and dependencies in relation to the others[45].

41 Report FORESIGHT. *Perspektywa Technologiczna Kraków-Małopolska 2020. Mapy wiedzy dla Regionu Małopolski w Polsce*, Krakowski Park Technologiczny, Kraków 2009.

42 Raport *FORESIGHT. Perspektywa Technologiczna Kraków-Małopolska 2020. Raport strategiczny 20 technologii*, Kraków 2010.

43 A. Rogut, B. Piasecki, *Foresight jako instrument kształtowania przyszłości polskiego przemysłu tekstylnego. Podręcznik metodyczny dla projektu „Nowoczesne technologie dla włókiennictwa. Szansa dla Polski"*, Łódź 2010 [electronic document]. Access: portaltechnologii.pl/pdf/metodologia.pdf [Accessed: 23.02.2012].

44 U. Narkiewicz, K. Lubkowski, *Foresight obszaru tematycznego „chemia" województwa zachodniopomorskiego (raport końcowy)*, Szczecin 2010 [electronic document]. Access: www.rsi.wzp.pl/download/index/biblioteka/6425 [Accessed: 23/02/2012].

45 L. Michalczuk (ed.), *Żywność i żywienie w XXI wieku. Scenariusze rozwoju polskiego sektora rolno-spożywczego*, Społeczna Wyższa Szkoła Przedsiębiorczości i Zarządzania w Łodzi, Łódź 2011.

From the perspective of technology mapping methodology, this is another of the initiatives highlighting the importance of identifying links between technologies, as well as determining the level of technology readiness.

Foresight technologiczny przemysłu INSIGHT 2030 (*The INSIGHT 2030 Industry Technology Foresight*) project assumed, among other things, the identification of future technologies key to the strategic development of Polish industry in the next 20 years. As part of the work, research areas were identified and a number of expert opinions involving a wide range of experts were performed within them. In this work, attention was paid to determining the state of technology development, comparing the state in Poland and the European Union, identifying factors determining the development of technologies, or identifying research and partner institutions related to technologies. For some areas, publications documenting foresight studies indicating strategically important technologies were also reviewed. The implementers also undertook the development of a technology cluster atlas, which was made temporarily available online. It took the form of lists of technology clusters, along with the location in Poland of cities and scientific and industrial centers associated with the development of the selected technology. As part of the further work to carry out the *technology roadmapping* method, the project implementers again paid attention to the relevance of the issue of determining the level of technology development and identifying the main research centers, as well as addressing the aspect of the main applications of technology and its importance in terms of the environment, economy and society[46,47].

From the perspective of the technology mapping methodology, the following can be considered important within the framework of the implementation of the aforementioned project: an attempt to record selected technologies in the form of a publicly available technology database that also includes the spatial location of units related to its development, as well as an indication of the importance of such technology characteristics as the state of technology development, the determinants of its development, its impact in terms of environment, economics and society, a record of research centers, or an indication of technology–related publications.

Foresight technologiczny „NT FOR Podlaskie 2020" Regionalna strategia rozwoju nanotechnologii (The technology Foresight initiative "NT FOR Podlaskie 2020. Regional Strategy for Nanotechnology Development) is a project that used the technology mapping method in accordance with the methodology developed by the author of this report. Technology mapping was intended to provide the broadest possible knowledge of the

46 *Foresight technologiczny przemysłu INSIGHT 2030. Streszczenie analizy końcowej*, IZTECH, Warszawa 2011, [electronic document]. Access: www.fortech2030.pl/images/stories/downloads/pdf/streszczenie_wersja_polska.pdf, [Accessed 03.07.2012]; Foresight technologiczny przemysłu INSIGHT 2030, [online], remote access: www.fortech2030.pl, [Accessed 03.07.2012].

47 Atlas klastrów technologicznych projektu *Foresight technologiczny przemysłu INSIGHT 2030*, [online]. Access: www.fortech2030.pl/atlas-klastrow, [Accessed: 20.05.2013].

technologies of interest to the project implementers. Knowledge of nanotechnologies, due to their high degree of specialization, was based on expert knowledge. However, it is worth noting that on the basis of the information obtained, not only data aggregation was carried out, but also further self-analysis was carried out to expand the created knowledge base. As part of the work carried out, a knowledge collection tool was developed – technology description sheets, which were then organized and published as technology cards.

The technology characteristics were taken as[48]:

- general description of the technology;
- purpose of application;
- the necessary resources in the form of equipment for the unit using the technology;
- records of patents and scientific publications relevant to technology development;
- the benefits and barriers associated with its development;
- possibly existing technology components;
- technologies that determine the development of a given solution and those affected by it;
- technological alternatives;
- the advantages of the technology described in the card;
- locations (identified by experts) of major technology development centers in the region and the country.

An example of a technology card is presented in Figure 3. The project work also included the presentation of knowledge about technologies not only from the perspective of a single technology, but also focused on aggregate statements, and in their context determined the level of technology readiness using the *technology readiness level* (TRL) indicator, the attractiveness and feasibility of technologies, the overall level of costs required for technology development, as well as the current and potential scale of application of the analyzed solutions. In addition, taking into account the possibility of dependencies between the development of individual technologies, a map of relations between technologies (based on expert assessment) was created. This map is shown in Figure 4. In addition, maps of relations of technology development centers, a map of relations of scientific centers, a map of relations of technology manufacturers/producers and a map of relations of experts developing technologies were drawn up. These visualizations were based on a relationship defined as interest in the same technological areas, and thus showed existing and/or potential networks. The relationship map of technology development centers is presented in Figure 5**.**

48 A. Kononiuk (ed.), A. Gudanowska (ed.), *Kierunki rozwoju nanotechnologii w województwie podlaskim. Mapy. Marszruty. Trendy*, Politechnika Białostocka, Białystok 2013.

obszar: PRZEMYSŁ MASZYNOWY I TRANSPORT kategoria: NANOMETALE KONSTRUKCYJNE

T38 TECHNOLOGIE NANOSTRUKTURYZACJI METALI I STOPÓW LEKKICH W SZCZEGÓLNOŚCI OPARTE NA METODACH DUŻEGO ODKSZTAŁCENIA PLASTYCZNEGO

Krótka charakterystyka technologii

Metody dużego odkształcenia plastycznego (*Severe Plastic Deformation – SPD*) opierają się na koncepcji przekształcenia mikrometrycznej struktury ziarnistej konwencjonalnych materiałów metalicznych w strukturę nanometryczną przez reorganizację struktury dyslokacyjnej tworzącej się w wyniku odkształcenia plastycznego. Dla małych wartości odkształcenia defekty generowane w materiale, głównie dyslokacje, rozmieszczone są przypadkowo. Po przekroczeniu pewnego krytycznego odkształcenia ulegają one przegrupowaniu tworząc ściany dyslokacyjne, komórki oraz pasma ścinania. Wraz ze wzrostem wartości odkształcenia zmniejszają się odległości pomiędzy granicami ziaren a w efekcie powstaje struktura złożona z ziaren o nanometrycznych wielkościach i dużych kątach dezorientacji granic ziaren. Rozdrobnienie ziarna do rozmiarów nanometrycznych wpływa na właściwości mechaniczne metalu, a zwłaszcza jego wytrzymałość. Zgodnie z zależnością Halla-Petcha można spodziewać się znacznego wzrostu wytrzymałości materiału wraz ze zmniejszaniem się średniej średnicy ziaren.

Cel stosowania technologii

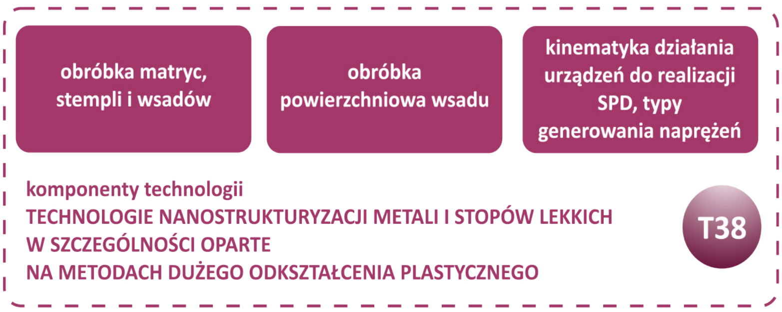
Rozdrobnienie ziarna i wytworzenie litego materiału o wyższych właściwościach mechanicznych.

Przykłady obecnego zastosowania

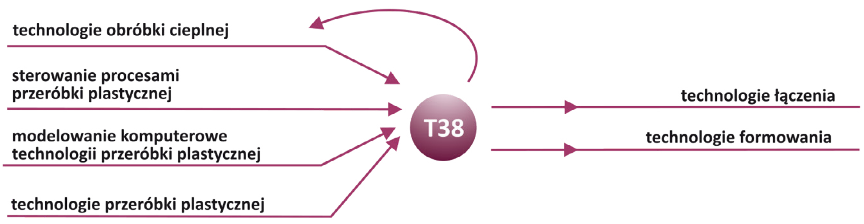
Bioinżynieria – protezy i implanty, siatki katalityczne, MEMS, przewody elektryczne, nity.

Niezbędne wyposażenie laboratorium

prasy wraz z układami wspomagającymi (walce, stemple, matryce, układy chłodzące i inne w zależności od metody SPD) – podstawowe wyposażenie
sprzęt do badania właściwości mechanicznych (twardościomierze, maszyny wytrzymałościowe) – opcjonalnie
urządzenia do charakterystyki struktury (mikroskopy TEM, SEM) – opcjonalnie



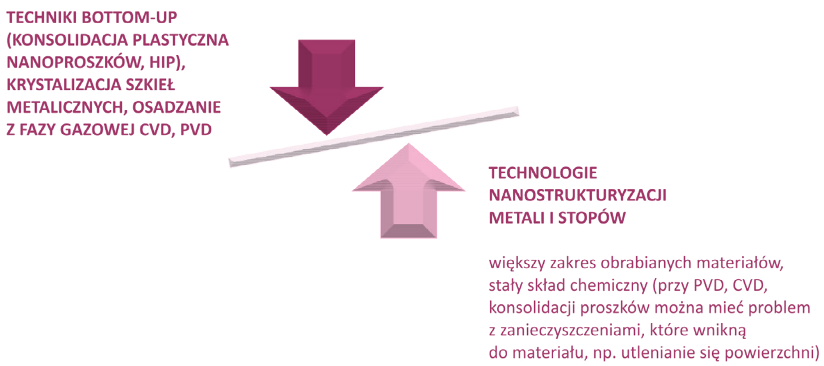
Determinanty technologii T38 i technologie zależne od T38 w bezpośredniej ocenie eksperckiej



Korzyści i bariery rozwoju technologii T38

+	–
zmniejszenie masy i wymiarów elementów konstrukcyjnych przy zachowaniu ich wysokich właściwości wytrzymałościowych a co za tym idzie zmniejszenie emisji CO_2 do atmosfery	koszty eksploatacji urządzeń do realizacji procesów SPD
	małe rozmiary produktów
	niska stabilność termiczna otrzymanych nanometali, problemy z łączeniem tych elementów (nie można ich spawać)
pojawienie się nowych rynków zbytu	koszty uruchomienia produkcji
	problemy z chłodzeniem podczas procesów SPD

Alternatywne technologie i ewentualna przewaga technologii T38



Eksperci z zakresu technologii T38

prof. dr hab. inż. Leopold Adam Berkowski
dr hab. inż. Małgorzata Grądzka-Dahlke
prof. dr hab. inż. Jan Ryszard Dąbrowski
prof. dr hab. inż. Henryk Antoni Dybiec
dr hab. inż. Halina Maria Garbacz
dr inż. Mariusz Kulczyk
prof. dr hab. inż. Małgorzata Anna Lewandowska
dr hab. inż. Grzegorz Jan Niewielski
dr inż. Lech Jan Olejnik
dr Wacław Józef Pachla
prof. dr hab. inż. Zbigniew Pakieła
prof. dr hab. inż. Maria Wiesława Richert

Najważniejsze patenty związane z technologią T38

- P-388 159 – Sposób kątowego wyciskania wyrobów, zwłaszcza metalowych
- P-379858 – Przyrząd do obróbki plastycznej metali
- P-379859 – Sposób kształtowania odkuwek i przyrząd do kształtowania odkuwek matrycą segmentową
- P-379860 – Sposób plastycznego kształtowania wyrobów metalowych i przyrząd do plastycznego kształtowania wyrobów metalowych
- P-379861 – Przyrząd do obróbki plastycznej matrycą segmentową

Wykaz podstawowej literatury związanej z technologią T38

K. J. Kurzydłowski (red.), M. Lewandowska (red.), *Nanomateriały inżynierskie, konstrukcyjne i funkcjonalne*, PWN, Warszawa 2010

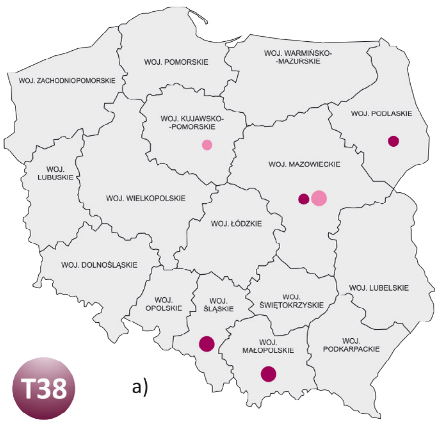
M. Lewandowska, K. J. Kurzydlowski, *Synergic effects of grain refinement and precipitation strengthening*, "Journal of Materials Science", nr 45, 2010, s. 4877-4883

K. J. Kurzydlowski, *Modelling of the microstructure and properties in the length scales varying from nano- to macroscopic*, "Bulletin of the Polish Academy of Sciences", nr 58, 2010, s. 217-226

R. Nowak, F. Yoshida, D. Chrobak, K. J. Kurzydlowski, T. Takagi, T. Sasaki, *Nanoindentation Examination of Crystalline Solid Surface*, [w:] *Encyclopedia of Nanoscience and Nanotechnology*, H. S. Nalwa (red.), American Science Publishers, 2011, s. 313-374.

W. Lojkowski, A. Gedanken, E. Grzanka, A. Opalinska, T. Strachowski, R. Pielaszek, A. Tomaszewska Grzeda, S. Yatsunenko, M. Godlewski, H. Matysiak, K. J. Kurzydlowski, *Solvothermal synthesis in a microwave reactor of nano-crystalline zinc oxide doped with Mn^{2+}, Co^{2+} and Cr^{3+} ions*, "Journal of Nanoparticle Research", nr 11, 2009, s. 1991-2002

Mapy lokalizujące wyróżnione przez ekspertów ośrodki naukowe oraz wytwórców/producentów zajmujących się technologią *Technologie nanostrukturyzacji metali i stopów lekkich w szczególności oparte na metalach dużego odkształcenia plastycznego* (T38): (a) w Polsce; (b) w województwie podlaskim



Ośrodki naukowe
WOJEWÓDZTWO PODLASKIE
Politechnika Białostocka
POLSKA
Politechnika Warszawska
Akademia Górniczo-Hutnicza w Krakowie
IMIM PAN, Kraków
Politechnika Śląska
Uniwesytet Śląski w Katowicach
Wytwórcy/producenci
WOJEWÓDZTWO PODLASKIE
-
POLSKA
Mennica Metale Szlachetne SA
Mikro-met
Instytut Wysokich Ciśnień PAN
Politechnika Warszawska

Fig. 3. Example of a technology card – project Foresight technologiczny „NT FOR Podlaskie 2020" Regionalna strategia rozwoju nanotechnologii

Source: A. Kononiuk (ed.), A. Gudanowska (ed.), Kierunki rozwoju nanotechnologii w województwie podlaskim. Mapy. Marszruty. Trendy, Politechnika Białostocka, Białystok 2013, pp. 97–99.

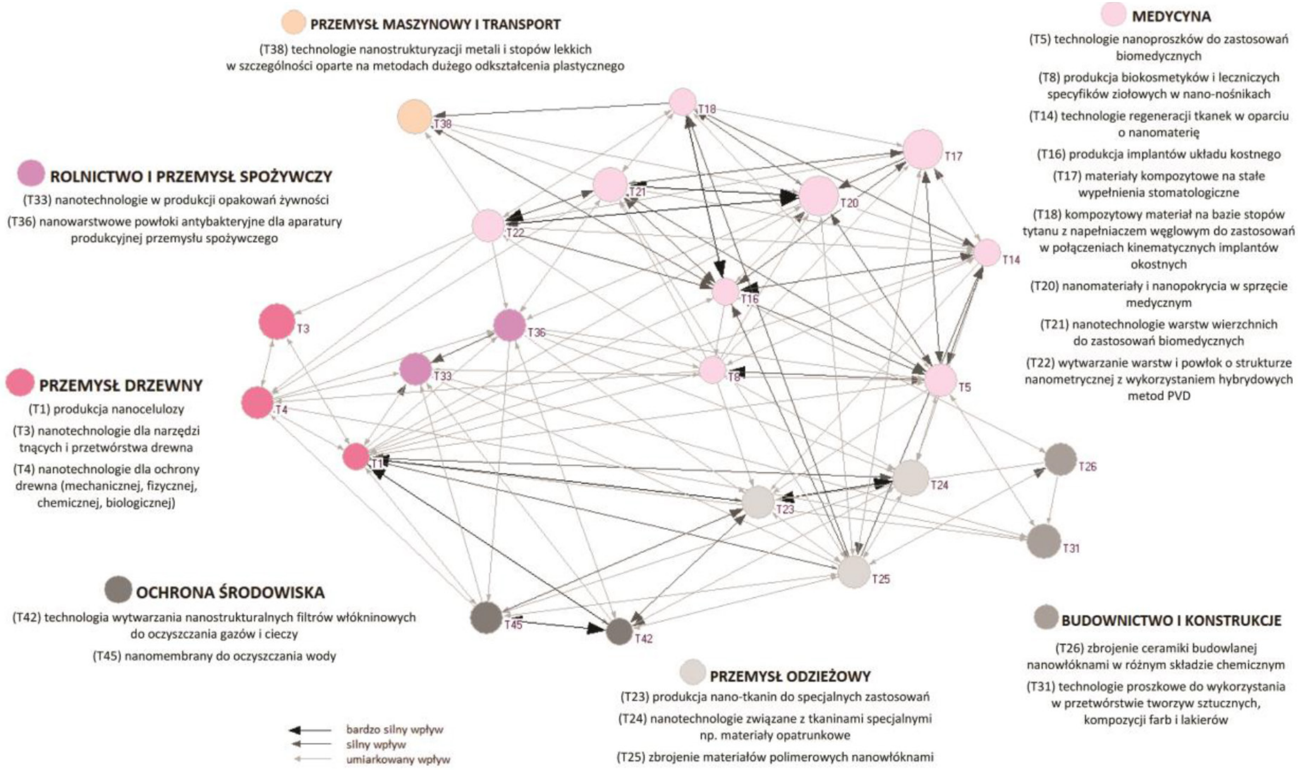


Fig. 4. Example of a map of technology relations – project *Foresight technologiczny „NT FOR Podlaskie 2020" Regionalna strategia rozwoju nanotechnologii*

Source: A. Kononiuk (ed.), A. Gudanowska (ed.), Kierunki rozwoju nanotechnologii w województwie podlaskim. Mapy. Marszruty. Trendy., Politechnika Białostocka, Białystok 2013, p. 18.

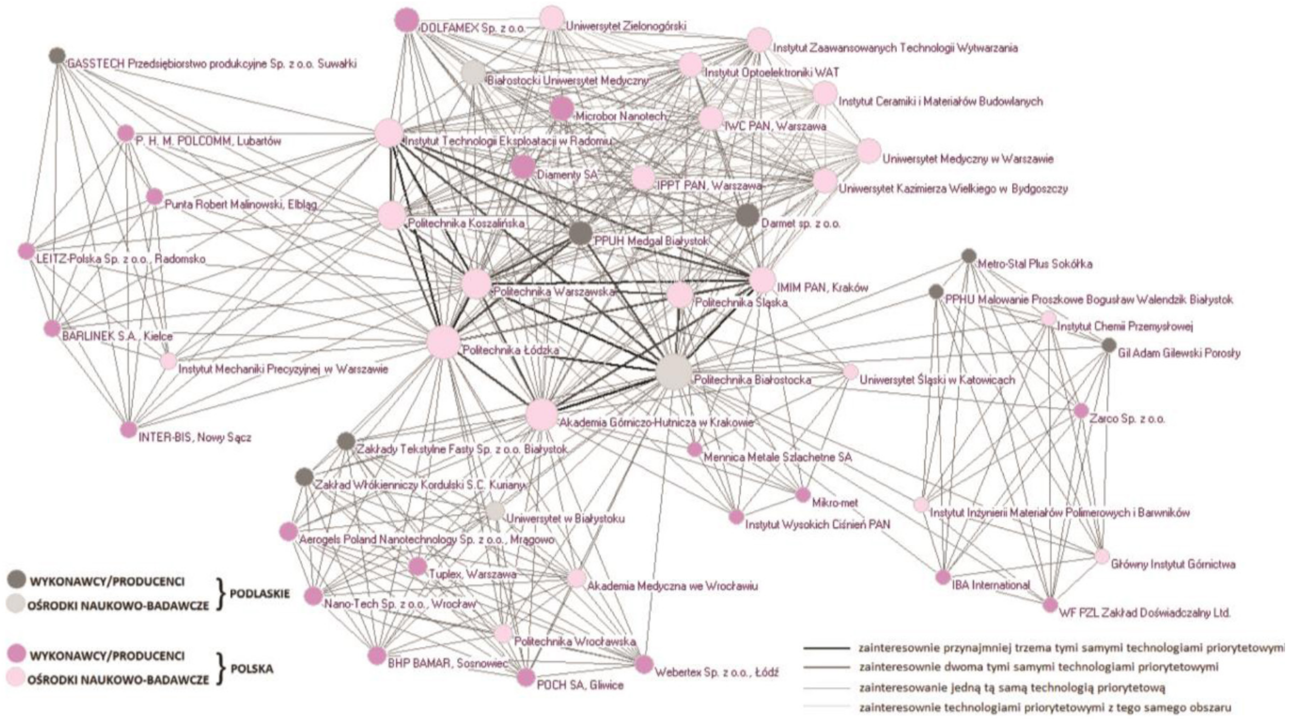


Fig. 5. Example map of relations of technology development centers – project *Foresight technologiczny „NT FOR Podlaskie 2020" Regionalna strategia rozwoju nanotechnologii*

Source: A. Kononiuk (ed.), A. Gudanowska (ed.), Kierunki rozwoju nanotechnologii w województwie podlaskim. Mapy. Marszruty. Trendy., Politechnika Białostocka, Białystok 2013, p. 26.

The presented project was the first in Polish research to provide a proposal that comprehensively captures the implementation of the technology mapping methodology with its structured course. Available literature sources provide a detailed insight into the various aspects of the implementation of the methodology[49,50,51,52,53,54]. The course of the methodology was finally documented in the monograph[55], and its general scheme is presented in Figure 6.

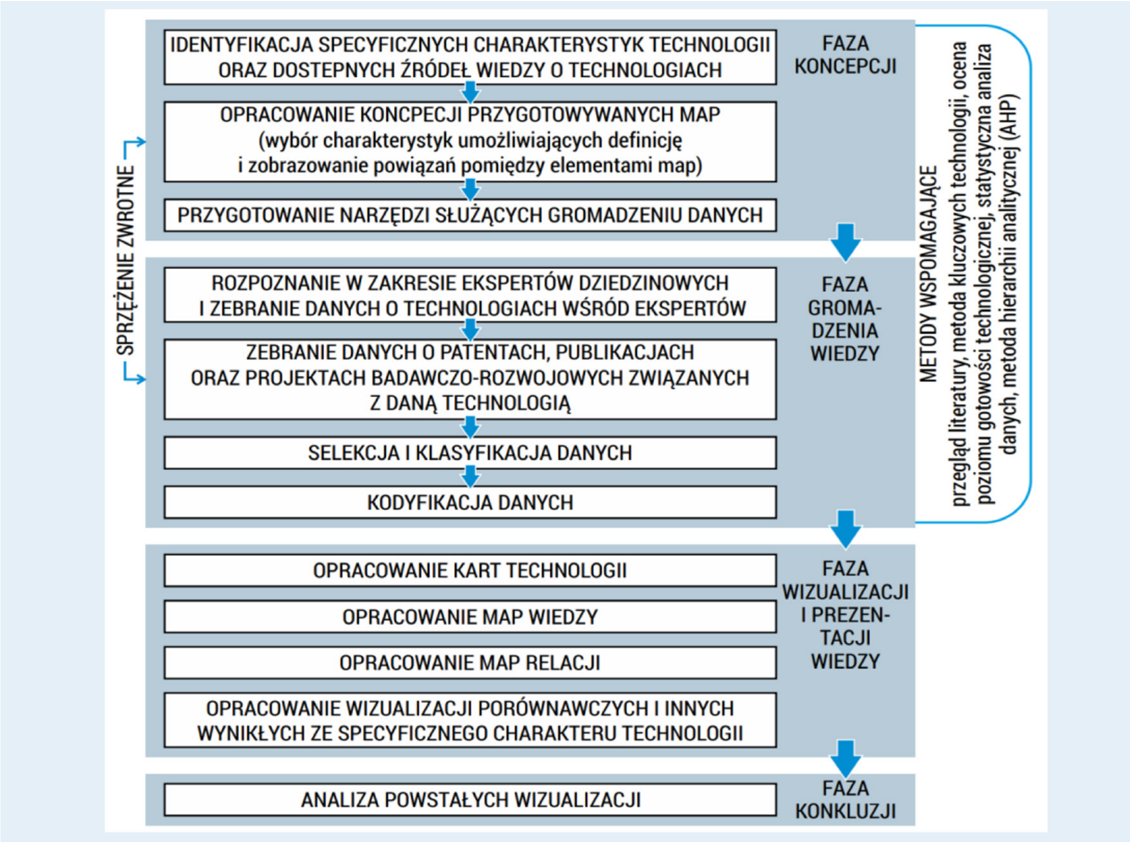


Fig. 6. Technology mapping methodology according to A. Gudanowska

Source: A. E. Gudanowska, *Metodyka mapowania technologii w badaniach foresight*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2021, DOI: 10.24427/978-83-67185-01-1, p. 139.

49 A. Kononiuk (ed.), A. Gudanowska (ed.), *Kierunki rozwoju nanotechnologii w województwie podlaskim. Mapy. Marszruty. Trendy*, Politechnika Białostocka, Białystok 2013.

50 A. Gudanowska, *Maps of Technology Experts Relations and Technology Development Centers Relations as a Part of the Technological Knowledge Base in Foresight Studies*, "Journal of System and Management Sciences," 2016, no. 6/1.

51 A. Gudanowska, *Mapa relacji technologii jako narzędzie wspomagające proces ich selekcji*, [in:] R. Knosala (ed.) „Innowacje w zarządzaniu i inżynierii produkcji" 2016, T. 1, Opole, Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją.

52 A. E. Gudanowska, *Technology mapping as a tool for technology analysis in foresight studies. The idea of the method and an example of its practical application*, Technology Management Conference (ITMC), 2014 IEEE International, 2014.

53 A. E. Gudanowska, *Technology mapping – proposal of a method of technology analysis in foresight studies*, "Business: Theory and Practice" 2016, no. 17(3).

54 J. Nazarko, J. Ejdys, A. E. Gudanowska, K. Halicka, A. Kononiuk, A. Magruk, Ł. Nazarko, *Roadmapping in Regional Technology Foresight: A Contribution to Nanotechnology Development Strategy*, "IEEE Transactions on Engineering Management" 2020.

55 A. E. Gudanowska, *Metodyka mapowania technologii w badaniach foresight … op. cit.*

The aforementioned monograph also compiled a list of possible technology characteristics that may be important for creating a technology card. At the same time, it was pointed out that each group of technologies may have its own peculiarities in terms of their characteristics (such as the rate of consumption of raw materials or evaluation of the efficiency of a given technology), but the research work presented in the literature to date allows the identification of certain general characteristics that can be described as standard. Any research initiative that (even narrowly) conducts technology mapping through the use of a technology description card as a data collection tool should include a reconnaissance stage in terms of the characteristics that can be included on the card. The set of selected characteristics should include standard elements, as well as possibly include some specific characteristics, depending on the level of detail assumed in the study being carried out. Figure 7. shows suggestions for the standard characteristics proposed in the monograph.

Charakterystyka	Uwagi
Krótka charakterystyka technologii	–
Cel stosowania technologii	–
Faza rozwoju technologii	przy wykorzystaniu na przykład skali poziomu gotowości technologicznej (indeks TRL)
Przyporządkowanie zakresu stosowania danej technologii	skala jednostkowa lub masowa, zastosowanie obecne i potencjalne
Korzyści z wdrożenia danej technologii	–
Bariery rozwoju technologii	–
Wyposażenie laboratorium	bieżące, niezbędne wyposażenie laboratorium pozwalające na prace rozwojowe w zakresie danej technologii
Wymagania finansowe	bieżące, niezbędne do poniesienia nakłady finansowe w celu rozwoju technologii
Koszty wdrożenia	nakłady finansowe związane z wprowadzeniem danej technologii do przedsiębiorstw
Ośrodki naukowe	zajmujące się daną technologią na określonym obszarze
Producenci/wytwórcy technologii	wdrażający, wykorzystujący i/lub rozwijający daną technologię na określonym obszarze
Kluczowi eksperci	z zakresu technologii na określonym obszarze
Technologiczne determinanty rozwoju	wskazanie technologii determinujących rozwój rozważanej
Technologiczne kierunki oddziaływania	wskazanie technologii, na które silnie wpływa technologia rozważana
Przykłady obecnego zastosowania technologii	–
Komponenty technologii	wskazanie czy technologia składa się z komponentów rozumianych jako jednostki, podsystemy lub inne technologie wchodzące w jej skład
Technologie alternatywne	wskazanie czy istnieją lub są w fazie opracowywania technologie alternatywne oraz ich identyfikacja
Wyróżniki technologii	wskazanie ewentualnej przewagi rozważanej technologii w odniesieniu do alternatywnych rozwiązań
Stopień akceptacji społecznej	określenie ogólnego bądź bardziej szczegółowego (w zależności od celu prowadzonego mapowania) stopnia akceptacji społecznej dla rozwoju danej technologii
Ocena nowoczesności technologii	określenie stopnia nowowczesności/innowacyjności danego rozwiązania, jego usytuowania w zidentyfikowanych trendach rozwojowych (na podstawie oceny eksperckiej)
Oddziaływanie ekologiczne	określenie ogólnego bądź bardziej szczegółowego (w zależności od celu prowadzonego mapowania) stopnia oddziaływania danej technologii na środowisko
Regulacje	wskazanie istniejących specjalnych regulacji dotyczących technologii na poziomie kraju oraz unii europejskiej
Wykaz podstawowej literatury dotyczącej technologii	–
Najistotniejsze patenty związane z technologią	–

Fig. 7. Standard characteristics which are possible elements of the technology description card according to A. Gudanowska

Source: A. E. Gudanowska, *Metodyka mapowania technologii w badaniach foresight*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2021, DOI: 10.24427/978-83-67185-01-1, pp. 142–144.

As mentioned earlier, the research procedure carried out in the project is the closest to the proper understanding of technology mapping in the opinion of the author of this report. For this reason, it is the one that became the initial source material for the work on developing a technology mapping methodology dedicated to cluster enterprises in the metalworking industry. From this perspective, it is important to emphasize the following aspects of the activities undertaken in the described project: creation a tool for collecting data on technologies, creation of a technology card (capturing the general description, purpose and scale of application of the technology, resources, benefits of and barriers to development, costs of implementation/development, alternative solutions, a list of patents and scientific works related to technologies), the need to locate and catalogue technology development centers, the need to present links between technologies, as well as centers and experts related to its development. This list is supplemented by the characteristics also listed in Figure 7. resulting from further work by the researcher involved in the project.

Author Z. Chyba, conducting a comparison of key methods of technology assessment and selection in relation to the development of technological entrepreneurship of various entities, pointed out that these issues in relation to both individual technologies and the entire technology portfolio is an area still in need of development. Within the framework of the conducted analysis, it is possible to note the characteristics of technologies identified by the author that appear in the implementation of various methods. These include:[56]

- age of technology;
- level of advancement of technology (in terms of characteristics: high, medium or low);
- versatility of the technology;
- utilitarian nature of the solution;
- ease of copying or appropriation;
- economic value of the technology;
- potential to provide a technological advantage;
- impact from social, ecological or ethical perspectives;
- time required for implementation or use;
- number of suppliers or outlets in an area;
- innovation of the solution;
- competitiveness of the solution;
- patent protection aspect.

56 Z. Chyba, *Porównanie wybranych metod oceny i selekcji technologii*, „Zeszyty Naukowe Politechniki Śląskiej, seria: Organizacja i Zarządzanie" 2016, No. 93(1957), pp. 73–84.

Considering the operationalization of the technology mapping methodology, we can highlight here the characteristics that can be used in the technology card relating to the life cycle phase, level of sophistication, versatility, innovativeness, competitiveness, ease of copying, advantages associated with the use of the solution, social, ethical and environmental impact, or the time of introduction of the solution.

In a study conducted by 4CF Ltd. on the Mazovian metal industry, an analysis was conducted that included summary statistics for all entities in the sector registered during the period of the study (capturing size and economic potential, industry structure, areas of geographic concentration and records of association organizations) and the selection of 120 companies with the highest innovative potential from among all analyzed companies. For them, data on their activity was collected and a qualitative analysis was carried out based on data from automated NLP analysis of the entities' websites, conducted interviews and workshops. It is noteworthy that in the performed qualitative analysis, an extensive record of words characterizing the activities of the entities was made and analyzed in terms of their occurrence[57] .

From the perspective of technology mapping, inspiration can be drawn here from the identification of areas of geographic concentration of entities for the purposes of summary statements that can be created for companies. The analysis of the occurrence of words characterizing the activities of enterprises performed as part of the qualitative analysis is also an interesting study, although in the opinion of the author of the report it would be worth supplementing it with an analysis of the co–occurrence of the collected words from the perspective of the entire analyzed group of enterprises along the lines of bibliometric analyses. This could provide inspiration when searching for new innovative solutions implemented in cooperation between entities.

In the context of technology mapping, an interesting position in the Polish literature is also the work of K. Halicka[58]. It presents the author's methodology of prospective technology analysis (PAT). While the implementation of the entire methodology is expected to ultimately lead to the determination of future directions of technology development, certain elements of the methodology relate to the analysis of the current state of technology development. Figure 8. shows the methodology of prospective technology analysis in the version of the operationalized research procedure dedicated to the road construction area, where it was used.

57 4CF sp. z o.o., *Analiza potencjału i trendów rozwojowych branży metalowej na Mazowszu,* research report, Warszawa 2018. Access: https://innowacyjni.mazovia.pl/upload/pages/1677/1677–0.pdf [Accessed: 22.07.2023].

58 K. Halicka, *Prospektywna analiza technologii: metodologia i procedury badawcze*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2016.

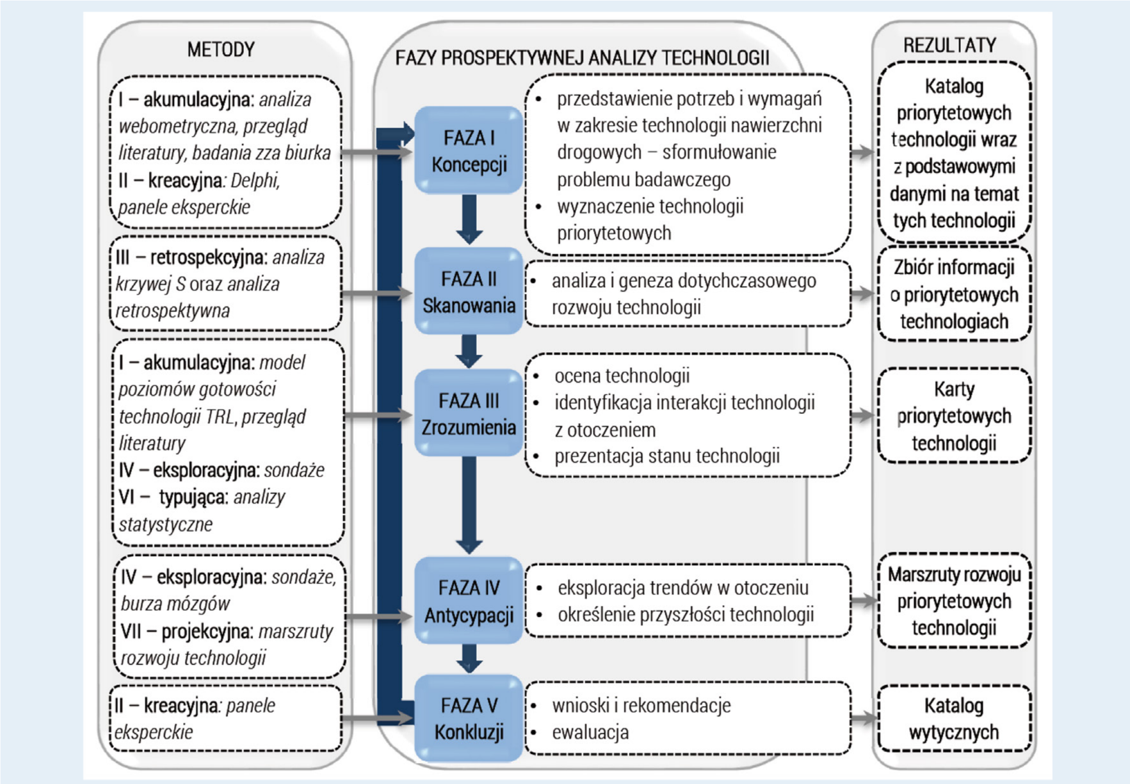


Fig. 8. Methodology of prospective analysis of technology according to K. Halicka – dedicated to the project *Perspektywy i kierunki rozwoju konstrukcji oraz rozwiązań materiałowo-technologicznych nawierzchni drogowych w aspekcie ochrony środowiska i zrównoważonego rozwoju (Prospects and directions of development of construction and material and technological solutions of road pavements in the aspect of environmental protection and sustainable development)*

Source: K. Halicka, *Prospektywna analiza technologii: metodologia i procedury badawcze*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2016, p. 129.

The elements of the methodology related to technology mapping presented in the described publication were consistent with the work and idea presented in the introduction of this report. Within K. Halicka's methodology (Figure 8.), it is worth noting, in addition to the assumption regarding the construction of technology priority charts, the use of the TRL indicator for assessing technology readiness and attention to the literature review for technology presentation and understanding. K. Halicka noted the relevance of the following characteristics in relation to individual road pavement technologies:[59]

- purpose and scope of use;
- technology-related keywords;
- level of innovation in technology;
- originality of technology;
- level of improvement with respect to existing solutions;
- benefits of its application;
- convenience of use;
- need to use hard-to-reach materials;

59 K. Halicka, *Prospektywna analiza technologii..., op. cit.*

- complementing other solutions available on the market;
- capabilities to solve technical problems;
- cost and degree of implementation;
- application examples;
- manufacturers/producers;
- technology components;
- degree of public acceptance;
- advantages in technical and environmental terms.

The research work also evaluated the technologies in terms of their competitiveness, usability, environmental and social aspects. The final characteristics selected and presented in the technology cards relating to road pavements are shown in Figure 9. (a–b).

NAZWA TECHNOLOGII

Tech1: Mieszanki mineralno-asfaltowe z lepiszczem gumowo-asfaltowym

KRÓTKA CHARAKTERYSTYKA TECHNOLOGII

Technologia dotyczy zastosowania rozdrobnionej gumy ze zużytych opon samochodowych do modyfikacji asfaltów drogowych oraz mieszanek mineralno-asfaltowych. Lepiszcze gumowo-asfaltowe (*asphalt rubber*) według normy ASTM D-8 określa się jako mieszaninę lepiszcza asfaltowego, gumy ze zużytych opon samochodowych oraz ewentualnie z dodatków obniżających lepkość. Składniki gumowe stanowią w tej mieszaninie co najmniej 15% w stosunku do masy lepiszcza i wchodzą w reakcję z gorącym asfaltem, zwiększając znacznie objętość. Właściwości lepiszczy gumowo-asfaltowych i mieszanek mineralno-gumowo-asfaltowych są porównywalne z właściwościami polimeroasfaltów i mieszanek z lepiszczami modyfikowanymi polimerem.

CEL STOSOWANIA TECHNOLOGII

Poprawa właściwości technicznych i trwałości nawierzchni asfaltowych, co przekłada się na efekt ekonomiczny oraz przyjazne dla środowiska zagospodarowanie odpadów gumowych.

SŁOWA KLUCZOWE ZWIĄZANE Z TECHNOLOGIĄ

guma, opony, asfalt, mieszanka mineralno-asfaltowa, lepiszcze gumowo-asfaltowe

ZAKRES STOSOWANIA DANEJ TECHNOLOGII

(1) Dotychczas w Polsce nie stosowana powszechnie (nawierzchnie w Dynowie na Podkarpaciu, ulica Wołoska w Warszawie).
(2) Możliwość zastosowania do budowy dróg wszystkich kategorii ruchu oraz do nawierzchni na obiektach mostowych.

PRZYBLIŻONY KOSZT TECHNOLOGII

Koszt stosowania lepiszcza gumowo-asfaltowego jest około 16% wyższy od asfaltu tradycyjnego ale porównywalny z kosztem stosowania polimeroasfaltu.

STOPIEŃ WDROŻENIA TECHNOLOGII

(1) Technologia posiada niezależne oceny lub potwierdzenia zgodności ze standardami technicznymi i została wdrożona przez co najmniej kilku producentów na pełną skalę techniczną.
(2) W Polsce komercyjnie nie została wdrożona.

POZIOMY GOTOWOŚCI TECHNOLOGICZNEJ

TRL8 – Zakończono badania i demonstrację ostatecznej formy technologii. Potwierdzono osiągnięcia docelowego poziomu technologii.

WYTWÓRCY/PRODUCENCI ZWIĄZANI Z DANĄ TECHNOLOGIĄ W POLSCE

Strabag S.A., Lotos S.A., Bisek Sp. z o.o., BIK – Projekt Łomża Sp. z o.o.

WYTWÓRCY/PRODUCENCI ZWIĄZANI Z DANĄ TECHNOLOGIĄ NA ŚWIECIE

D&H Equipement, Phoenix Industries, CEI Enterprises, Massenza S.R.L., Signus Madrid, Bennighoven Gmbh&Co.KG.

PRZYKŁADY OBECNEGO ZASTOSOWANIA TECHNOLOGII

Cienkie warstwy ścieralne z mieszanek mineralno-gumowo-asfaltowych BBTM o obniżonej emisji hałasu na ul. Wołoskiej w Warszawie, mieszanka mineralno-gumowo-asfaltowa SMA 8 na warstwę ścieralną dróg miejskich o dużym natężeniu ruchu w Dynowie na Podkarpaciu, cienkie warstwy gumowo-asfaltowe SAM i SAMI rozpowszechnione głównie w USA (California, Teksas).

Fig. 9a. Example of technology card (part 1/2) – project *Perspektywy i kierunki rozwoju konstrukcji oraz rozwiązań materiałowo–technologicznych nawierzchni drogowych w aspekcie ochrony środowiska i zrównoważonego rozwoju (Perspectives and directions of development of construction and material and technological solutions of road pavements in the aspect of environmental protection and sustainable development)*

Source: K. Halicka, *Prospektywna analiza technologii: metodologia i procedury badawcze*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2016, p. 157.

In further research work, K. Halicka focused on developing *technology roadmaps* that captured the development of technology over time. However, of interest may be the layers highlighted there concerning:[60]

- relationship with the environment by identifying the potential benefits of technology implementation from an environmental, social and economic perspective;
- application areas;
- functional attributes;
- components;
- technology–related entities;
- phases in the technology life cycle;
- level of research work directions;
- necessary human, financial and material resources.

The visualizations also included information related to barriers to technology development and the inclusion of technologies in the system of interactions with other technological solutions[61].

From the perspective of technology mapping methodology, it is worth noting here the creation of a tool for collecting data on technologies with numerous proposals for possible technology characteristics, emphasizing the need to record entities related to technology development, and pointing to technologies as interrelated. Among the characteristics used in the described studies that can inspire the creation of a technology card are: assessment of technological readiness, purpose, scope, areas and examples of application of the technology, its general characteristics (also by providing keywords), components, assessments in terms of the level of innovation, originality, convenience of use, level of social acceptance, competitiveness, usability, and from an environmental and social perspective, identification of costs associated with the development of the technology, benefits of its implementation, necessary resources, and reference to existing solutions (level of improvement, use of rare materials, complementarity with existing solutions, advantages).

60 K. Halicka, *Prospektywna analiza technologii ..., op. cit.*

61 K. Halicka, *Prospektywna analiza technologii ..., op. cit.*

KORZYŚCI Z WDROŻENIA DANEJ TECHNOLOGII

Większa odporność na koleinowanie, mniejsza podatność na starzenie, większa trwałość zmęczeniowa, odporność na spękania odbite i spękania niskotemperaturowe, zmniejszenie hałasu i zmniejszenie poślizgu opon. Poprawa właściwości technicznych i trwałości nawierzchni asfaltowych, co przekłada się na efekt ekonomiczny oraz przyjazne dla środowiska zagospodarowanie odpadów gumowych, niższy koszt technologii w pełnym cyklu życia w porównaniu z technologiami mieszanek mineralno-asfaltowych z lepiszczem niemodyfikowanym.

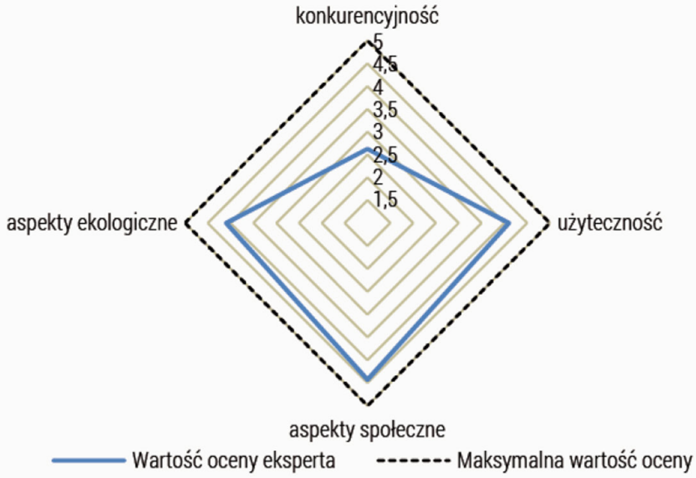
KOMPONENTY TECHNOLOGII ROZUMIANE JAKO JEDNOSTKI, PODSYSTEMY LUB INNE TECHNOLOGIE WCHODZĄCE W SKŁAD DANEJ TECHNOLOGII

Technologia produkcji rozdrobnionej gumy ze zużytych opon samochodowych, technologia produkcji lepiszczy gumowo-asfaltowych, technologia produkcji mieszanek mineralno-asfaltowych z lepiszczem gumowo-asfaltowym.

STOPIEŃ AKCEPTACJI SPOŁECZNEJ DLA ROZWOJU DANEJ TECHNOLOGII

Bardzo wysoki.

OCENA EKSPERCKA TECHNOLOGII



EWENTUALNA PRZEWAGA TECHNOLOGII W KONTEKŚCIE ISTNIEJĄCYCH ALTERNATYWNYCH TECHNOLOGII

Aspekt techniczny: wysoka odporność zmęczeniowa i odporność na starzenie nawierzchni z mieszanek mineralno-asfaltowych z lepiszczem gumowo-asfaltowym w porównaniu z alternatywnymi technologiami nawierzchni asfaltowych.

Aspekt ekologiczny: zagospodarowanie materiałów, które obecnie stanowią odpad przemysłowy lub stosowane są jako paliwo energetyczne o wysokim stopniu emisji zanieczyszczeń w procesie spalania, możliwość układania cieńszych warstw niż w alternatywnych, tradycyjnych technologiach, co spowoduje zmniejszenie zapotrzebowania na kruszywa drogowe.

Fig. 9b. Example of technology card (part 2/2) – project *Perspektywy i kierunki rozwoju konstrukcji oraz rozwiązań materiałowo–technologicznych nawierzchni drogowych w aspekcie ochrony środowiska i zrównoważonego rozwoju (Perspectives and directions of development of construction and material and technological solutions of road pavements in the aspect of environmental protection and sustainable development)*

Source: K. Halicka, *Prospektywna analiza technologii: metodologia i procedury badawcze*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2016, p. 158.

In other work conducted, researcher K. Halicka conducted an assessment of selected gerontechnologies. While the approach presented in this research was not technology mapping, it referred to the assessment of its current state in terms of selected criteria.

It is these criteria that can be an interesting inspiration when creating a technology mapping methodology. Among them are: technological maturity, innovativeness of the technological solution, its usability, functionality, assessment of demand, marketing, environmental or socio–ethical aspects[62,63].

From the perspective of technology mapping methodology, it is worth noting here the assessments that characterize the technology and the broad context of these assessments indicating, in the opinion of the author of this report, the important interaction of the technology with the environment.

Technology in the context of the technology management process has also become the focus of E. Krawczyk–Dembicka's research in cluster enterprises affiliated with the metalworking cluster. The author, as a result of extensive literature studies, analysis of case studies and surveys, presented the author's view of the technology management process. Given the possibility of using the technology mapping method in the technology management process at its selected stages, as signaled in the introduction to the report, some activities and observations made by the researcher are worth noting here. Especially since the area of her research is in line with the area for which the technology mapping methodology is to be developed. From the perspective of the technology card, it is worth noting the technology classifications used by E. Krawczyk–Dembicka. Here the author proposed a classification into technologies[64] :

- preparatory,
- metalworking,
- assembly/disassembly,
- advanced automation,
- other, causing difficulty in assigning to the above groups.

This classification was created at the stage of developing the research concept. On the other hand, the second classification that the author identified after the research was based on the generally accepted types of manufacturing technologies that can be identified in the metalworking industry[65] :

- machining,
- forming processes,

62 K. Halicka, *Gerontechnology – the assessment of one selected technology improving the quality of life of older adults*, “Engineering Management in Production and Services” 2019, no. 11(2), pp. 43–51.

63 K. Halicka, *Personal Care Robots for Senior Adults – Analysis and Assessment of the Current State of Selected Gerontechnology*,”Multidisciplinary Aspects of Production Engineering” 2018, no. 1(1), pp. 867–873.

64 E. Krawczyk-Dembicka, *Model zarządzania technologiami w przedsiębiorstwie klastrowym – studium przypadku*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2019.

65 E. Krawczyk–Dembicka, *Model zarządzania technologiami w przedsiębiorstwie klastrowym ..., op. cit.*

- heat treatment,
- chemical treatment,
- surface treatment,
- assembly/disassembly technologies,
- advanced automation technologies,
- enabling technologies.

Both classifications are possible to use directly in the technology card, as well as in the enterprise card. In addition to grouping technologies, the author paid attention to such characteristics of technologies as descriptions of technologies, the purpose of using technologies, the production effect, specific conditions of the technological process, or innovativeness of solutions. The author's work can also be an important source in the field of enterprise card. So far, the studies described in the report have mainly focused on the need for records of entities related to the development of technology and have not provided guidance related to the characteristics of their description. In the work and research of E. Krawczyk–Dembicka, it is possible to identify a number of elements that can become characteristics on the enterprise card. These include:[66]

- company size;
- organizational structure (narrowed down to parts directly related to technology);
- number of employees in technology–related departments (the entity's human resources potential);
- number of production facilities operating for the company under study;
- cooperation markets (indicative of the scale of international expansion of the surveyed entities);
- available machinery;
- territorial scope of activity;
- technology groups used/developed in the entity (grouped, for example, according to the described classifications, consistent with those used in the technology cards);
- production scale;
- sources of technology;
- sources of funding;
- initiators of the development and implementation of new technologies in the entity;
- activities implemented as part of the technology management process;
- timeframe of the technology management process;
- areas of cooperation in technology management within the cluster.

66 E. Krawczyk–Dembicka, *Model zarządzania technologiami w przedsiębiorstwie klastrowym ..., op. cit*.

The author also identified possible variants of some of the characteristics in her surveys. Using the results of her research in an enterprise card would significantly facilitate its completion. Thus, in the aspect of ways of acquiring technologies, the charter could include the following choices: technologies made available through cooperation with the Metalworking Cluster, effect of cooperation with other enterprises, effect of cooperation with a research and development unit (for example, a university), upgrading "obsolete" technologies to new needs of the enterprise, technologies developed and produced in the enterprise, and purchase of the technologies (for example, machinery or knowledge).

In the context of sources of financing, it would be worth considering the use of the following options: the enterprise's own funds, leasing, bank credit, lease of machinery/equipment, and public funds to support business activities (for example, state budget funds, European Union funds). From the perspective of the initiators of the development and implementation of new technologies in the enterprise, the following set of possible options can be used: Board of Directors, Director/Manager of Development Department, Director/Manager of Technology Department, Employees/Project Team, Customer, market–driven need/market niche, market trends, business owner, other.

The last characteristic, which was enriched by the range of possible choices, is the area of technology management cooperation in the cluster: idea of technology emergence, development of new technology assumptions, technology identification, technology selection, technology acquisition, technology exploitation, technology protection, technology development, search for new areas of technology application, technology implementation in the industry, conducting educational activities (for example, courses or training), technology dissemination in the market, organization of work in Advanced Cooperation Groups, organization of study visits to enterprises, subsidizing participation in trade fairs, joint purchasing, other[67,68,69].

From the perspective of metal industry technology mapping methodology, E. Krawczyk-Dembicka's research is an extremely inspiring position that provides both relevant characteristics and their description, especially in the context of the enterprise charter. Also noteworthy are the aspect of the classification of technologies in the metal industry and the characteristics of technologies used by the author, which include basic descriptions of technologies, the purpose of their use, the expected production effect, the conditions of the technological process, or the innovativeness of technological solutions.

Interesting from the perspective of operationalizing the technology mapping methodology is the research conducted by K. Klincewicz and A. Manikowski. The researchers, developing their proprietary algorithm for technology evaluation, ranking

67 E. Krawczyk–Dembicka, *Model zarządzania technologiami w przedsiębiorstwie klastrowym ..., op. cit*.

68 W. Urban, E. Krawczyk-Dembicka, *An In-depth Investigation of Technology Management Process in the Metal Processing Industry*, "European Research Studies Journal" 2020, no. 23/1, pp. 115–136.

69 W. Urban, E. Krawczyk-Dembicka, *Technology Management as a Process – a View from In-Depth Studies in Metal Processing Companies*, [in:] Hamrol A. (ed.), Kujawinska A. (ed.), Barraza M.F.S. (ed.), *Advances in Manufacturing II,* Springer International Publishing, Cham 2019, pp. 58–69.

and selection (O–R–S), conducted extensive studies on, among other things, technology evaluation criteria. The entire algorithm is consists of several steps involving the determination of the specifics of the decision–making situation, the selection of appropriate criteria, expert evaluation of technologies according to the selected criteria (proper technology evaluation) and the mutual validity of the criteria (a series of comparative evaluations), and the construction of a technology ranking.

For the review conducted in the report, the technology evaluation criteria developed by the authors seem to be the most relevant, as they highlight important aspects of technologies on which knowledge should be accumulated in the context of their future evaluation.

As already mentioned, the work carried out by the authors is very extensive and describes in detail the process of selecting criteria and the experience of other researchers in determining them. For the purposes of technology mapping, it is important to note the main groups of criteria. These include innovation and competitiveness (in relation to competing solutions operating in the market, but also available patents and barriers to entry), which, according to the authors' indications, are important especially for new solutions. Other criteria include the connection of the technology with the organization's strategy, the previous experience of the organization–supplier of the technology (also in the financial aspect) and its importance for the entity (also in terms of the relationship with the production effect, owned physical and human resources and the benefits of implementing the solution).

Marketing criteria covering the needs of customers (also in terms of the benefits achieved by them) and market conditions, areas of application of the technology, technical criteria (detailed parameters of the technology, an assessment of the level of technological maturity and ways to solve specific problems appears here), reference to production technologies (as related to technologies designed to support manufacturing processes), the aspect of patent protection, social, ethical and ecological criteria (reference to the impact of the technology on society and the environment) were also taken into account. In their publication, the authors pointed out that different criteria can have different meanings depending on the specific situation of evaluation and ranking[70].

Figure 10. shows the possible decision–making scenarios assumed by the researchers and the sets of criteria assigned to them.

70 K. Klincewicz, A. Manikowski, *Ocena, rankingowanie i selekcja technologii*, Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa 2013.

Scenariusz decyzji o rankingowaniu technologii	Najważniejsze grupy kryteriów
decyzje o nowym produkcie	• kryteria dotyczące innowacyjności • kryteria dotyczące konkurencyjności • kryteria strategiczne • kryteria marketingowe • kryteria dotyczące zastosowań technologii • kryteria techniczne • kryteria dotyczące ochrony patentowej • kryteria społeczne i etyczne • kryteria ekologiczne
decyzje o nowym procesie wytwórczym lub zakupie technologii dla własnych potrzeb	• kryteria techniczne • kryteria dotyczące technologii produkcyjnych • kryteria dotyczące zastosowań technologii • kryteria społeczne i etyczne • kryteria ekologiczne
decyzje o inwestycji w organizację-dostawcę lub nawiązaniu z nią współpracy partnerskiej	• kryteria dotyczące innowacyjności • kryteria dotyczące konkurencyjności • kryteria strategiczne • kryteria dotyczące doświadczeń organizacji-dostawcy • kryteria dotyczące znaczenia technologii dla organizacji-dostawcy • kryteria marketingowe • kryteria dotyczące zastosowań technologii • kryteria techniczne • kryteria dotyczące ochrony patentowej • kryteria społeczne i etyczne • kryteria ekologiczne

Fig. 10. Importance of technology evaluation criteria depending on the decision–making situation according to K. Klincewicz

Source: K. Klincewicz, A. Manikowski, *Ocena, rankingowanie i selekcja technologii*, Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa 2013, p. 124.

In their publication, the authors have provided a very comprehensive list of detailed issues that can be used during the implementation of the O–S–R algorithm in the form of questions with lists of possible answers (to be selected or completed). Although this list can be considered too detailed from the perspective of technology mapping methodology, some of the statements included in it can be extremely useful when creating a technology card. Table 1. shows a selection of these that the author of the report believes can be used in a technology card.

Table 1. Examples of selected technology characteristics possible for use in a technology card, with detailed variants of characteristics (based on the research of K. Klincewicz)

Technology characteristics	Details (proposed variants of the state of characteristics)
1	2
Level of innovation	➲ a highly innovative solution that meets a well-known customer need ➲ an innovative solution that offers tangible benefits to customers ➲ an innovative solution, the purchase of which is not associated with clear benefits for customers ➲ slight improvements over existing solutions ➲ a solution that does not show significant improvements over known and used solutions
Originality in relation to the current state of knowledge	➲ groundbreaking innovation on a global scale ➲ an innovative solution on a national scale, but with foreign (international) counterparts ➲ innovative solution in the industry/application area, but with counterparts in other industries/areas ➲ not very original solution, similar to existing offerings in the industry/application area scale
Advantage over existing alternatives	➲ a solution is groundbreaking and may influence changes in the strategies of alternative solution providers ➲ a solution is a significant improvement on previously known alternatives ➲ a solution is an improvement on previously known alternatives ➲ a solution is a slight improvement on previously known alternatives ➲ a solution does not offer improvements over previously known alternatives
Impact of existing alternatives on the market position of technologies	➲ there are no similar alternatives ➲ there is an alternative technology that is not currently competitive ➲ there is an alternative technology with limited applications ➲ there is an alternative technology with potentially wide applications ➲ there is an alternative technology that dominates the market
Impact of technology diffusion on the market position of alternative solutions	➲ the proliferation of technologies may create additional sales opportunities for alternatives ➲ technology uptake will not be related to changes in sales levels of alternatives ➲ the spread of technology will lead to a slight decline in sales of alternatives ➲ the spread of technology will lead to a significant decline in sales of alternatives ➲ the proliferation of technology will eliminate alternative solution providers from the market

Table 1. con. Examples of selected technology characteristics possible for use in a technology card, with detailed variants of characteristics (based on the research of K. Klincewicz)

1	2
The nature of barriers to entry	➲ very high barriers to entry, based, among other things, on unique access to materials or components ➲ high barriers to entry, based, among other things, on patent protection ➲ medium barriers to entry, based, among other things, on exclusive licensing agreements with suppliers of key components ➲ low barriers to entry ➲ direct competitors already exist and offer comparable solutions
Range of specialized applications	➲ universal–purpose technology – various possible applications in many areas ➲ fundamental technology for more than one industry ➲ fundamental technology for a specific industry ➲ technology with single, specific application ➲ difficult to determine
Degree of complexity	➲ technology that forms the basis for building a system solution and further ➲ procurement of technological components ➲ technology used independently ➲ technology suitable for use in conjunction with other solutions, components of a larger system solution ➲ technology that can only be used in conjunction with other solutions ➲ difficult to determine
Level of complexity	➲ a very high degree of complexity, making it impossible to copy the technology even after taking possession of a copy of the solution and subjecting it to reverse engineering ➲ high degree of complexity, making it impossible to copy the technology based on testing the solution and reading the user's technical documentation ➲ medium degree of complexity, allowing the technology to be copied based on observation of the solution ➲ low degree of complexity, allowing to copy the technology based on reading materials promoting the solution or learning the basic principle of operation ➲ technology is very simple and can be copied from observation
Life cycle phase	➲ innovative technology, starting its life cycle – has significant potential for further development ➲ technology under dynamic development ➲ technology in the phase of widespread use in the market ➲ mature technology in decline ➲ technology obsolete – no potential for further development

Table 1. con. Examples of selected technology characteristics possible for use in a technology card, with detailed variants of characteristics (based on the research of K. Klincewicz)

1	2
Potential for legal protection	➲ by way of full patent protection ➲ through limited patent protection (due to disclosure of part of the technology or use of essential components from third--party suppliers) ➲ through limited patent protection (due to patentability in countries other than Poland and inadmissibility of patenting in Poland or the difficulty of enforcing certain patent claims) ➲ by way of secrecy, protection of know–how and protection of documentation under copyright law ➲ protection is no longer possible
The nature of social and ethical impacts	➲ spread of technology will affect the creation of new jobs ➲ spread of technology will affect the development of the domestic industry ➲ spread of technology will benefit human health and quality of human life ➲ spread of the technology will bring aesthetic benefits (e.g., landscape or smell value) ➲ spread of technology will bring benefits in terms of improving the image of the national economy ➲ spread of technology will benefit the creation of an industry standard ➲ spread of technology can be a source of social problems ➲ spread of technology may directly lead to violations of universally applicable moral norms or laws ➲ spread of technology can cause problems for human health or the quality of human life ➲ proliferation of technologies may be a source of aesthetic problems (related, for example, to landscape or smell nuisance) ➲ development, manufacture, use or disposal of the technology may be a source of disease risk for employees of companies using the solution ➲ development, production, use or disposal of technology can be a source of disease risk for people who are not employees of the organization (stakeholders) ➲ proliferation of technology may cause privacy issues for potential users or others ➲ proliferation of technology may give rise to problems of discrimination, inequality or social justice disorder ➲ technology dissemination is in line with the country's policies (including innovation, environmental and regional development policies), in particular their goals and priority areas

Table 1. con. Examples of selected technology characteristics possible for use in a technology card, with detailed variants of characteristics (based on the research of K. Klincewicz)

1	2
Nature of ecological impacts	➲ proliferation of technology can provide tangible benefits in terms of increased safety in the industry ➲ proliferation of technology can be a source of environmental problems ➲ manufacturing of the technology or a product based on it can be seen as an inefficient use of natural resources (including water) in the manufacturing, use or disposal process ➲ manufacturing of the technology or a product based on it can be seen as an inefficient use of energy in the manufacturing, use or disposal process ➲ manufacture of a technology or a product based on it can be seen as a source of environmentally burdensome emissions and waste from the manufacturing, use or disposal process ➲ manufacturing of the technology or a product based on it can be seen as a source of increased risk of accidents or failures in the manufacturing, use or disposal process ➲ manufacture of the technology or a product based on it requires the use of hazardous substances in the manufacturing, use or disposal process ➲ manufacturing of the technology or a product based on it will contribute to the saving of natural resources (including water) compared to the alternatives used so far ➲ manufacturing of the technology or a product based on it will contribute to energy savings compared to existing alternatives ➲ manufacture of the technology or a product based on it will contribute to a reduction in environmentally burdensome emissions and waste compared to existing alternatives ➲ manufacture of the technology or a product based on it will contribute to a reduction in the risk of accidents or accidents compared to the alternatives used so far ➲ manufacture of the technology or a product based on it will reduce the amount of hazardous substances in the manufacturing, use or disposal process compared to the processes of existing alternatives ➲ manufacture of the technology or a product based on it will allow use of secondary raw materials in the process of use or disposal

Source: Own work based on K. Klincewicz, A. Manikowski, *Ocena, rankingowanie i selekcja technologii*, Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa 2013, pp. 159–197.

The authors also proposed to classify the analyzed technologies into groups: technologies-products, machinery, equipment or process technologies, research and testing apparatus solutions, materials technologies, and technologies for regeneration and utilization[71] . However, considering the area for which the technology mapping methodology will be operationalized, the classifications proposed by E. Krawczyk--Dembicka seem more appropriate.

From the perspective of the technology mapping methodology in the described studies of K. Klincewicz and A. Manikowski, it is worth noting the extensively described criteria for assessing technologies, which can provide a hint of the characteristics that would be worth describing in technology cards. The analysis of this item of literature also allows some detailing of some of the possible characteristics to be used.

2.2. International experiences

Implemented in Denmark, the *Sensor Technology Foresight* research initiative included technology mapping as part of its activities, which was preceded by a scan covering the future of technology. The mapping was carried out after organizing the concepts related to the technologies under study. Based on the results of the literature review and workshops with experts, three dimensions of analysis focused directly on: technology, knowledge and skills, and products and market were defined for the technology mapping analysis. The first dimension involved classifying technologies according to the adopted scale. The second dimension involved the identification of scientific disciplines related to technology development, the necessary competencies related to production effects created by using technology, and illustrating the process of creating and disseminating knowledge related to technology through the presentation of two case studies. The third dimension, in turn, involved classifying the users of the technology and identifying the underlying areas of their application. Further work also required identifying the phase of technology development, assessing the impact of technologies on the market, and the uncertainty of the analyzed solutions[72, 73, 74] .

For the purpose of creating a technology mapping methodology in the described initiative, it is worth noting the aspect of organizing technologies by assigning them to predetermined areas, indicating the competencies necessary during the development and use of technologies, emphasizing the connection of technologies with scientific research, recording and classifying technology users and areas of application.

71 K. Klincewicz, A. Manikowski, *Ocena, rankingowanie i selekcja technologii ...*, op. cit.

72 P. D. Andersen, B. H. Jørgensen, B. Rasmussen, *Sensor Technology Foresight,* Risø National Laboratory, Roskilde, Denmark 2001, pp. 6, 10–19,23, 28–29.

73 P. D. Andersen, B. H. Jørgensen, L. Lading, B. Rasmussen, *Sensor foresight – technology and market,* “Technovation” 2004, no. 74, pp. 312–314.

74 P. S. Giesecke (ed.), P. Crehan (ed.), S. Elkins (ed.), *The European Foresight Monitoring Network Collection of EFMN Briefs – Part 1*, Office for Official Publications of the European Communities, Luxembourg 2008, pp. 123–126.

Also in Denmark, the *Danish Nano–science and Nano–technology for 2025* study was carried out, during which a mapping of Danish science and technology within nanotechnology was conducted. As part of the effort, based on data collected from companies and other institutions, as well as an analysis of publications, the most important entities related to technology development were identified[75].

From a technology mapping perspective, it is worth noting here the identification of the need for records of entities related to technology development.

In their publication, Yong–Gil Lee and Yong–Il Song presented a proposal for a method of analyzing technology clusters to determine the so-called *proximity of* technologies. At the same time, the authors stressed the importance and effectiveness of experts' expertise as a unique source of information when gathering knowledge about technologies. It was on the basis of the declaration of this knowledge that indicators were developed to determine the relationships between different technological solutions[76].

From the perspective of technology mapping, it is worth emphasizing here the aspect of identifying specialists related to technologies and basing the dependencies between technologies on the study of their level of domain knowledge.

An interesting take on technology analysis is the research work carried out by Canada's *Office of Technology Foresight* (OTF). During a panel on disruptive technologies organized as part of the undertaken activities, the implementers emphasized that the development of technology is closely linked to the development of the environment in terms of both the industry and the organization. After distinguishing the interrelated main technological areas, visualizations (referred to as technology maps) were developed, which showed the connections between the various technologies and application areas. The map also divided technologies and areas into disruptive and non–disruptive. The links determined which elements of the map would affect the development of the others[77].

From the perspective of the technology mapping methodology in the described project, special attention was paid to the inclusion of a group of technologies as an interrelated system of dependencies and the fact of the interplay between technology and its environment.

75 P. D. Andersen, B. Rasmussen, M. Strange, J. Haisler, *Technology foresight on Danish nano–science and nano–technology,* "Foresight" 2005, vol. 7, no. 6, pp. 65–67.

76 Yong–Gil Lee, Yong-Il Song, *Selecting the key research areas in nano-technology field using technology cluster analysis: A case study based on National R&D Programs in South Korea*, "Technovation" 2007, No. 27, pp. 57–64.

77 D. Denarius, *Synthesis Report on Foresight Models and Methodology. Report #04–02*, Office of Technology Foresight, Canada 2004; J. Smith, H. Masum, R. Bouchard, P. Kallai, E. Lockeberg, *Using S&T foresight to augment organizational tool kits: a Canadian institutional entrepreneurial experiment*, "R&D Management" 2004, vol. 34, no. 5, pp. 579–589.

Analyses in line with the idea of technology mapping were also presented in works by Changwoo Choi, Seungkyum Kim and Yongtae Park. In their publication, the authors emphasized the importance of not easily identifiable links that exist between technologies. In the work they undertook, they based their analysis on patents, relating them directly to specific technologies and emphasized the variability of the developed arrangement depending on time, market needs or emerging technologies[78].

Taking into account the methodology of technology mapping, the described research case is another work highlighting the dependencies occurring between technologies, as well as drawing attention to the importance of records of patents related to technologies.

Researchers A. L. Koppe, Ch. Lecou and S. Bröring also emphasized the role of patents in technology analysis. In their publication they used patent records to identify research areas in nanotechnology, which were supposed to indicate the level of national competence. Technology mapping based on patent analysis was intended to monitor technological competitors and emerging innovations, identify development opportunities and necessary competencies, and seek partners in technology development, as well as partners in sharing competencies that are not necessarily the resource of a single entity or economy[79].

From the perspective of technology mapping, it is worth noting the aspect of record-keeping and patent analysis, as well as the need, emphasized in the publication, to identify competencies related to technologies.

A paper by T. van der Valk, M. M. H. Chappin and G. W. Gijsbers, presents a proposed methodology for evaluating technological innovation networks. Two visualizations inspired by social network analysis were drawn up using software dedicated to this type of analysis. The focus was on participants in selected research projects, indicating their nature and areas of knowledge. Data was collected through interviews with representatives of the surveyed organizations[80]. In another of their works, the authors highlighted the possibility of using network analysis in technology analysis as a tool not only for technology-related literature studies or patent analysis, but also when analyzing technology-related units[81].

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78 Changwoo Choi, Seungkyum Kim, Yongtae Park, *A patent–based cross impact analysis for quantitative estimation of technological impact: The case of information and communication technology,* “Technological Forecasting and Social Change” 2007, No. 74, pp. 1296–1314.

79 A. L. Koppe, Ch. Lecou, S. Bröring, *Mapping emerging technology competencies in applied research: The development of nanochemistry in China and Germany,* The XXIV ISPIM Conference, Helsinki 2013.

80 T. van der Valk, M. M. H. Chappin, G. W. Gijsbers, *Evaluating innovation networks in emerging technologies*, “Technological Forecasting and Social Change” 2011, no. 78, pp. 25–39.

81 T. van der Valk T., G. Gijsbergs, *The use of social network analysis in innovation studies: mapping actors and technologies*, “Innovation: Management, Policy & Practice” 2010, vol. 12, no. 1, pp. 5–17.

Considering the methodology of technology mapping, the authors' observations emphasizing the role of units related to technology development and not only their cataloguing, but also the determination of the level of knowledge they possess in the field of technology, can be considered important.

The work of Y. Yasunaga, M. Watanabe and M. Korenga was a presentation of the process of creating a *technology roadmap* for national innovation policy. The procedure included a stage related to the preparation of a technology overview in static terms (at a specific point in time), referred to as the creation of a technology map/review. The map prepared was intended to show the importance and need for technology development, as well as areas of application and relations with other technological solutions[82]. Figure 11. shows the technology overview/map created by the authors of the publication.

From the perspective of the technology mapping methodology, it is noteworthy that once again the aspect of application areas and relationships between technologies was emphasized.

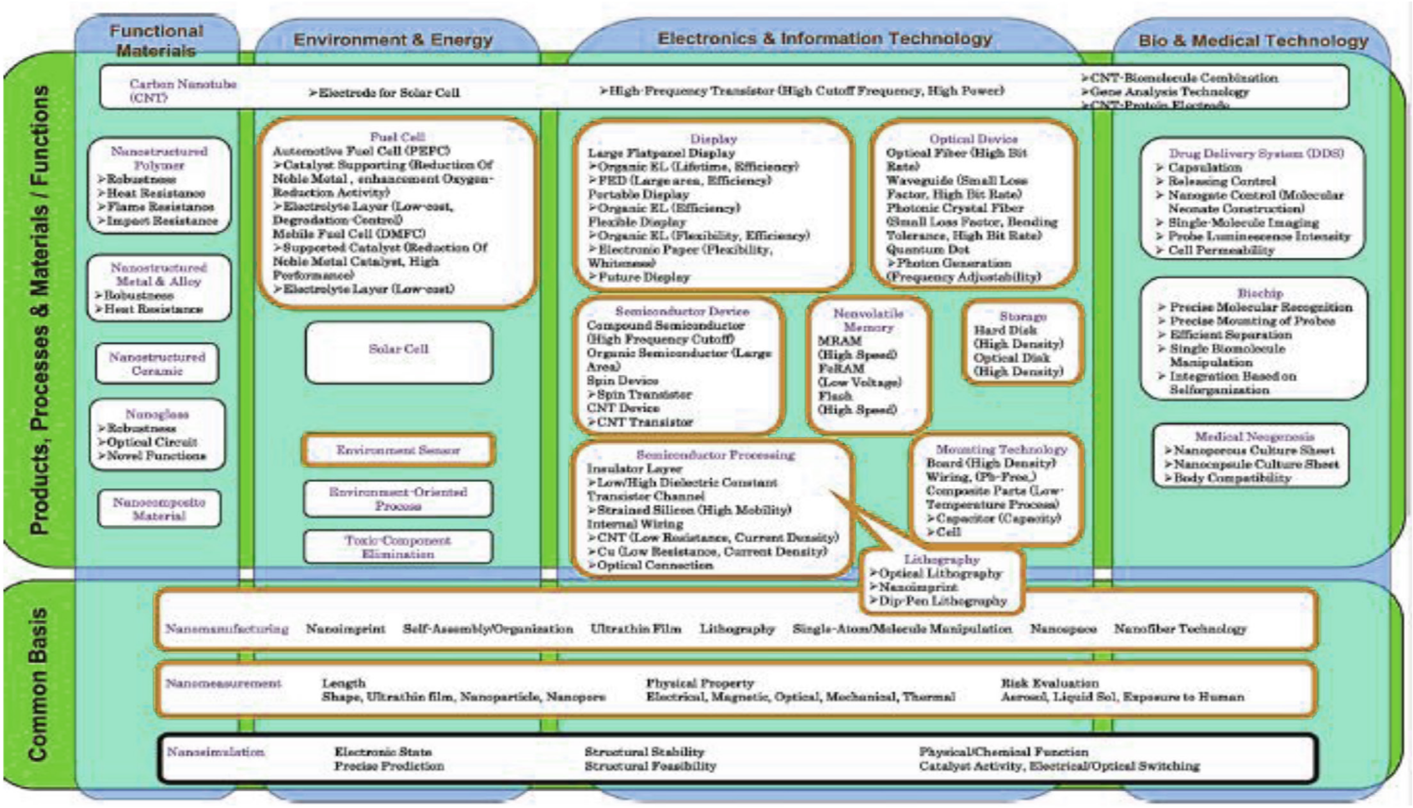

Fig. 11. Example of a technology overview/map

Source: Y. Yasunaga, M. Watanabe, M. Korenga, *Application of technology roadmaps to governmental innovation policy for promoting technology convergence,* "Technological Forecasting and Social Change" 2009, no. 76, p. 68.

82 Y. Yasunaga, M. Watanabe, M. Korenga, *Application of technology roadmaps to governmental innovation policy for promoting technology convergence*, "Technological Forecasting and Social Change" 2009, no. 76, pp. 61– 79.

A mapping of renewable energy technologies was conducted on behalf of *The International Center for Trade and Sustainable Development*, as documented in a paper by R. Vossenaar and V. Jha. The implementers of the study wanted to identify environmentally friendly key technologies and their accompanying products. The study also paid attention to the components of the technologies, the opportunities for technology consumers created by their use, as well as the barriers to entry into the market for which the analyzed technological solutions are dedicated. Technologies were also classified into predetermined categories derived from the analyzed research area, and were assigned products and components[83].

From the perspective of the technology mapping methodology, it is worth emphasizing the need noted by the researchers to identify technology components and link them to production effects, as well as the aspect of barriers to technology implementation and the opportunities they create for implementing units.

G. B. Benitez, N. F. Ayala and A. G. Frank conducted research on analyzing the technological capabilities of ecosystems based on the idea of *Industry 4.0*, their evolution and the opportunities they create for co–creating value for companies operating in this ecosystem. As part of the analysis, one of the identified research stages was technology mapping. As part of the mapping, attention was paid to such aspects as: indicating which technologies are offered by which enterprises, areas of technical knowledge in the enterprise in the field of a given technology, identification of forms of possible cooperation between enterprises, and barriers related to the implementation of technologies[84].

Considering the operationalization of the technology mapping methodology for the purposes of creating the technology card, it is worth noting the connection between technologies and the entities that offer and develop them, as well as the barriers associated with the introduction of a given technology. On the other hand, it is worth noting, for the purposes of the enterprise card, recording of areas of technical knowledge in entities, as well as declarations on possible forms of cooperation between entities.

In his publication on the methodology for creating a technology tree in the Internet of Things technology area, researcher A. Mansouri and his co–authors list and briefly explain essence of the technology mapping method as one of the methods for identifying technologies. According to the authors of the publication, technology mapping is intended to illustrate the relationship between technologies in a specific technological area or industry using various tools, including text, tables or network diagrams. A selected topic,

83 R. Vossenaar, V. Jha, *Technology Mapping of Renewable Energy, Buildings, and Transport Sectors: Policy Drivers and International Trade Aspects. An ICTSD Synthesis Paper*, ICTSD, Geneva 2010.

84 G. B. Benitez, N. F. Ayala, A. G. Frank, *Industry 4.0 innovation ecosystems: An evolutionary perspective on value cocreation*, “International Journal of Production Economics” 2020, no. 228.

concept, application or other information is taken as nodes, and links between the nodes indicate their relationships. The mapping can be based, for example, on the history of technologies, their correlations or cause–and–effect relationships between them. The result of technology mapping is usually a list of general technologies potentially applicable to specific industries[85].

From the perspective of technology mapping methodology, aspect of links between technologies and their development is worth noting here again.

An interesting analysis of technology identification defined as mapping is also described by A. Moro and co–authors. The analysis referred to the use of bibliometric analysis when identifying emerging technologies. Using specialized software, an analysis of the texts of selected scientific publications was carried out and a characterizing set of keywords was extracted. Then a qualitative cognitive analysis was carried out using the developed indicators and involving an international group of experts. The authors pointed out the usefulness of bibliometric analyses in the process of identifying new technological solutions[86].

From the perspective of operationalizing the technology mapping methodology, it is useful to note the importance, emphasized by the authors, of the knowledge relating to technology accumulated in scientific publications.

In their work, author A. A. Yevhenovych and co–authors defined technology mapping as one of the stages in the process of identifying in a group of technologies or directions, implementation of which is important for the development of a given entity, referred to as a technology package. By technology mapping, the researchers meant determining at which stage in its life cycle a technology is located. In the described analytical and research work, they suggested that the analysis of technology should include technical and economic aspects, and the evaluation of the technology package consists of, among other things,[87]:

- production and process efficiency analysis,
- material cost analysis,
- determination of the level of production,
- indication of regional and global markets,

85 A. Mansouri, M. M. Qaratlu, Z. Moezkarimi, Z. Kalatehaei, Z. Golmirzaei, *A Technology Tree for Internet of Things,* 7th International Conference on Web Research (ICWR), IEEE 2021, pp. 329–335.

86 A. Moro, E. De Castro Boelman, G. Joanny, J. Lopez Garcia, *A bibliometric–based technique to identify emerging photovoltaic technologies in a comparative assessment with expert review*, “Renewable Energy” 2018, no. 123, pp. 407–416.

87 A. A. Yevhenovych, O. V. Anatoliyovych, A. N. Oleksandrivna, *Strategic framework and methodical bases of technological package development management*, “Marketing and Management of Innovations” 2016, no. 3, pp. 170–180.

- identification of human resources,
- indication of the sources of materials necessary for the application of technology,
- identification of pilot technologies,
- aspects of technology transfer including information on patents and implementations.

The researchers also pointed out that technologies are entangled with each other[88].

From the perspective of operationalizing the technology mapping methodology, it is important to note the emphasis on the aspect of interconnectedness between technologies and use of selected characteristics that can be used in the technology card at the various stages of analysis, such as: determining the level of development of technologies according to life cycle phases, costs associated with the technology, identification of resources necessary for the development/ use of technologies, identification of patents related to technologies.

In the work of Iftikhar et al. A mapping of digital technologies for a specific audience was conducted. The researchers used a basic description of how the technology works, examples of implementation, and determined the level of development of the technology. At the same time, they pointed out that in future research in this area, it would be worthwhile to analyze patents related to the technology, as well as to determine the impact of the technology on financial and operational results related to the activities of the entity using the technology[89].

From the perspective of technology mapping methodology, the study can be taken as an inspiration for sample characteristics included in the technology card, such as the level of development of the technology, description of the technology, areas of its application, patent records or the aspect of impact on the entity developing/implementing the technological solution.

With regard to technology management, author B. Yoon presented various possibilities for visualizing strategic information, including the technology map. According to the author, the map provides an opportunity to create static and dynamic visualizations relating to the dominant features of the current technology and trends in its development. An example

88 A. A. Yevhenovych, O. V. Anatoliyovych, A. N. Oleksandrivna, *Strategic framework ..., op. cit*.

89 R. Iftikhar, Z. Pourzolfaghar, M. Helfert, *Omnichannel Value Chain: Mapping Digital Technologies for Channel Integration Activities*, [in:] A. Siarheyeva, C. Barry, M. Lang, H. Linger, & C. Schneider (ed.), *Information Systems Development: Information Systems Beyond 2020 (ISD2019 Proceedings)*, Toulon, France: ISEN Yncréa Méditerranée, 2019.

of a dynamic visualization was a *technology roadmap*, while a static one was a map of patents from the perspective of selected dimensions. Among other visualizations, the researcher included a technology tree (the characteristic attributes of a technology and how they are related), a technology network (links between technologies based, e.g. on patents), a technology matrix (a comparison of current technology solutions with possible alternatives), a technology curve (the life cycle of a technology using the S–curve) and a technology dictionary (machine–readable technology–related terms)[90].

From the perspective of operationalizing the technology mapping methodology, what is worth noting in this publication is the distinction between the static and dynamic view of technology, the aspect of recording and analyzing patents related to technology, the need to determine the level of development of technology, and the comparison of technology with alternatives.

Researcher P. P. Senna, along with co–authors, presented technology mapping as one of the methods for determining the current state of technology development and related elements necessary for use before starting to establish trends in technological development. In the presented approach, technology mapping was defined as a method conducive to analytical work aimed at expanding the accumulated knowledge, delivered in a form that facilitates its interpretation. The authors conducted the mapping of enabling technologies in the context of European supply chain scenarios.

The results of the mapping described in the publication were aimed at linking technologies to the scenarios created in parallel and provided an initial knowledge base for the creation of *technology roadmaps*. It was pointed out that it was important to note the need for an integrated approach to technology, as opposed to a stand–alone solution analysis. The authors identified four phases necessary in the process of technology mapping: identification, selection, evaluation and dissemination. The publication focuses particular attention on the last of these. It was assumed that this phase should include, in an overview manner, the combination of identified enabling technologies with future scenarios. The selected technologies were related to the strategic dimensions of the scenario (products and services, procurement and distribution, supply chain configuration, production systems, sales channels and sustainability). Mapping the technologies for each scenario made it possible to determine the technology profiles, which were then compared across scenarios. The results of the mapping were presented in the form of descriptions (texts) including, among other things, an indication of the technologies developed in a given scenario, scale of application of the technologies, areas of application, benefits for technology recipients (both individuals and businesses), or the impact on the environment. The descriptions were made paying special attention to the interactions of technologies[91].

90 B. Yoon, *Strategic visualization tools for managing technological information*, "Technology Analysis and Strategic Management" 2010, no. 22(3), pp. 377–397.

91 P. P. Senna, M. Stute, S. Balech, A. Zangiacomi, *Mapping Enabling Technologies for Supply Chains with Future Scenarios*, [in:] R. Fornasiero (ed.), S Sardesai (ed.), A. C. Barros (ed.), A. Matopoulos (ed.), *Next Generation Supply Chains. A Roadmap for Research and Innovation*, Springer 2021, pp. 147–165.

From the perspective of operationalizing the technology mapping methodology, it is important here to re–emphasize the aspect of interconnections and interactions between different technological solutions. Taking into account the technology card planned to be developed, such characteristics as: indication of the products and/or services created as a result of the use of technology, scale and areas of application of technology, benefits of its development/implementation/use or impact on the broader environment can serve as inspiration.

Links between technologies is a subject of interest also for B. Yan and J. Luo, who focused on creating a network of technologies based on patent analysis. Patent categories became the nodes of the network, which the authors believe are to some extent meant to reflect technology fields. The publication focused particular attention on filtering the network and extracting the strongest connections within its scope[92]. Figure 12. shows an example of a network of connections based on patent analysis.

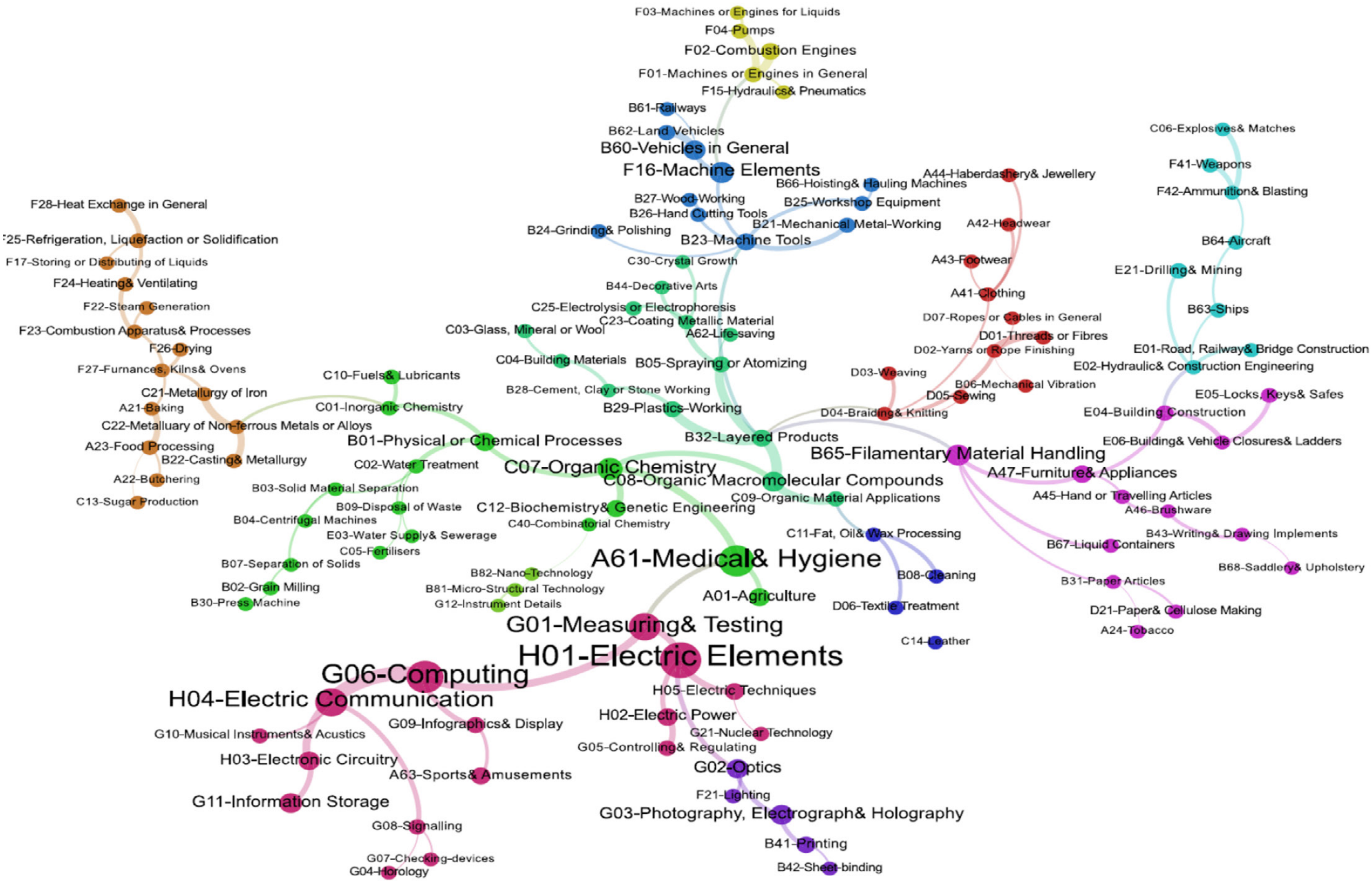

Fig. 12. Example of a technology network based on patent analysis

Source: B. Yan, J. Luo, *Filtering patent maps for visualization of diversification paths of inventors and organizations,* "Journal of the Association for Information Science and Technology" 2017, no. 68(6), p. 1557.

92 B. Yan, J. Luo, *Filtering patent maps for visualization of diversification paths of inventors and organizations,* "Journal of the Association for Information Science and Technology" 2017, no. 68(6), pp. 1551–1563.

From the perspective of technology mapping methodology, it is important to pay attention to the aspect of records and analysis of patents related to technologies, which should find their place in the technology card.

The idea of incorporating patent analyses into technology considerations is a line of research eagerly undertaken by foreign researchers. Knowledge about technology accumulated in patents often provides information about its functions, as well as about the final results of technology research, and also often provides the basis for determining the interaction of technologies[93, 94, 95, 96].

The importance of patent records and analysis should be considered in relation to the operationalization of technology mapping methodology. An aspect that has been highlighted quite extensively in foreign literature in the context of determining the current state of a technology is the **analyses for determining technological maturity, or the phase of its life cycle**. As part of these analyses, and as a separate, important aspect of determining the state of **a technology,** various authors propose the **use of patents and/ or analysis of publications related to a given technology**[97, 98, 99, 100, 101, 102].

In the conducted analyses, I. Ansari and his co–authors developed a model of readiness for *Industry 4.0* dedicated to organizations that plan to implement and use technologies that are counted among the solutions characteristic of the 4th industrial

93 Changwoo Choi, Seungkyum Kim, Yongtae Park, *A patent–based cross impact analysis for quantitative estimation of technological impact: The case of information and communication technology,* "Technological Forecasting and Social Change" 2007, no. 74, pp. 1296–1314.

94 A. K. Mittal, B. Mirdha, *Technology mapping using patents: A case of supply chain management*, Indian Institute of Technology, Kanpur, [online]. Access: www.fing.edu.uy/inco/eventos/icil05/04–thu/J2–Mittal.pdf, [Accessed: 05/10/2019].

95 R. K. Abercrombie, A. W. Udoeyop, B. G. Schlicher, *A study of scientometric methods to identify emerging technologies via modeling of milestones*, "Scientometrics" 2012, no. 91, pp. 237–342.

96 Hyoung–joo Lee, Sungjoo Lee, Byungun Yoon, *Technology clustering based on evolutionary patterns: the case of information and communication technologies*, "Technological Forecasting and Social Change" 2011, no. 78, pp. 953–967.

97 R. Lezama–Nicolás, M. Rodríguez–Salvador, R. Río–Belver, I. Bildosola, *A bibliometric method for assessing technological maturity: the case of additive manufacturing,* "Scientometrics" 2018, no. 117, pp. 1425–1452, doi.org/10.1007/s11192–018–2941–1.

98 K. Cauthen, P. Rai, N. Hale, L. Freeman, J. Ray, *Detecting technological maturity from bibliometric patterns,* "Expert Systems With Applications" 2022, no. 201, 117177, doi.org/10.1016/j.eswa.2022.117177.

99 H. Martínez–Ardila, A. Corredor–Clavijo, V. del Pilar Rojas–Castellanos, O. Contreras, J. Camilo Lesmes, *The technology life cycle of Persian lime. A patent–based analysis,* Heliyon 2022, vol. 8, no. 11, 11781, doi.org/10.1016/j.heliyon.2022.e11781.

100 P. Xiao, P. Qian, J. Xu, M. Lu, *A Bibliometric Analysis of the Application of Remote Sensing in Crop Spatial Patterns: Current Status, Progress and Future Directions*, "Sustainability" 2022, 14, 4104, doi.org/10.3390/su14074104.

101 B. Song, B. Yan, G. Triulzi, J. Alstott, J. Luo Song, *Overlay technology space map for analyzing design knowledge base of a technology domain: the case of hybrid electric vehicles,* "Research in Engineering Design" 2019, no. 30, pp. 405–423, doi.org/10.1007/s00163–019–00312–w.

102 D. Rotolo, I. Rafols, M. M. Hopkins, L. Leydesdorff, *Strategic Intelligence on Emerging Technologies: Scientometric Overlay Mapping*, "Journal of the Association for Information Science and Technology" 2015, 68(1), pp. 214–233.

revolution. As part of the research, the authors developed a list of dimensions and indicators of the model, which included, among others,[103]:

- degree of implementation of the *Industry 4.*0 strategy;
- technology–related capital expenditures;
- necessary hardware infrastructure and integrated management, production management and logistics systems associated with the implementation of the technology;
- requirements for data collection, information flow, data security and communication;
- products using selected technologies;
- degree of integration of services with customers;
- required skills and competencies of employees in the use of technology;
- customer interaction channels;
- knowledge sharing practices, including with external partners of the analyzed entity;
- level of management support for technology implementation;
- laws, regulations and intellectual property aspect.

From the perspective of operationalizing the technology mapping methodology, certain indicators and dimensions developed by the authors of the described publication can inspire the characteristics of the technology card, e.g.: aspect of finances, physical resources in the form of hardware infrastructure and software, human resources in the form of specific competencies, aspect of legal requirements necessary to be taken into account in the process of technology development, or the indication of production effects in the form of products and services related to the use of technology.

Researchers H. Arman and J. Foden, in one of their works, focused on monitoring and evaluating technological development for the needs of businesses by presenting a proposal for a *technology intelligence* (TI) process flow. According to the authors, all technology planning decisions should be made with the support of the broadest possible knowledge base about technology, so as to minimize the risk of inappropriate investment in technology or lack of investment when it is necessary. One of the important functions of the methodology presented in the article is cataloguing of technological information (its collection, categorization, storage and retrieval). The sources of the collected information can be external (e.g., suppliers, competitors, trade shows, conferences, publications and patents) and internal (R&D within the company, engineers and scientists, designers, operators, internal databases). The authors pointed out that in order to stay abreast

103 I. Ansari, M. Barati, M. R. Sadeghi Moghadam, M. Ghobakhloo, M. *An Industry 4.0 readiness model for new technology exploitation*, "International Journal of Quality & Reliability Management" 2023, ahead of print, doi.org/10.1108/IJQRM–11–2022–0331.

of technological developments and state–of–the–art solutions (occurring internally and externally to the entity) it is important to have established technology networks. The researchers considered such a network to be a list of key contacts who are knowledgeable about a particular technological area. As prerequisites for the implementation of the described methodology, its developers pointed out[104]:

- understanding of business plans, objectives and market requirements;
- analysis of the external environment (including legislative, legal, political, social and environmental aspects);
- review of patents and publications (journal articles, conference papers, reports, industrial journals, etc.);
- access to internal information sources;
- identification of technologies critical for the entity.

According to the TI methodology developed by authors of the article, one of its stages is the determination of the current *State–of–the–Art* (SOA) for each technology. The characteristics of technologies that, according to the researchers, should be included during this stage are presented in Figure 13. According to the authors, gathering the knowledge in the given scope and then supporting it with expert opinion provides a solid basis for comparative evaluation of technologies.

The authors also suggested the use of the *Technology Readiness Level* (TRL) measurement as a commonly understood and provided indicator for estimating technology maturity/capability. In further steps of the methodology, they also suggested referring to technology risks and opportunities (related to the market, products, materials and processes)[105].

Considering the technology mapping methodology from the perspective of the described analysis, it is worth noting the proposal to include information on publications and patents, key entities with knowledge of the technology, technology suppliers, technology experts, identification of market, social, environmental, legal and regulatory requirements related to the technology, level of technological readiness of the analyzed technological solutions, technology descriptions and main application areas, related materials, products and components.

104 H. Arman, J. Foden, *Combining methods in the technology intelligence process: application in an aerospace manufacturing firm,* "R&D Management" 2010, no. 40, pp. 181–194, doi.org/10.1111/j.1467–9310.2010.00599.x.

105 H. Arman, J. Foden, *Combining methods in the technology intelligence process ..., op. cit.*

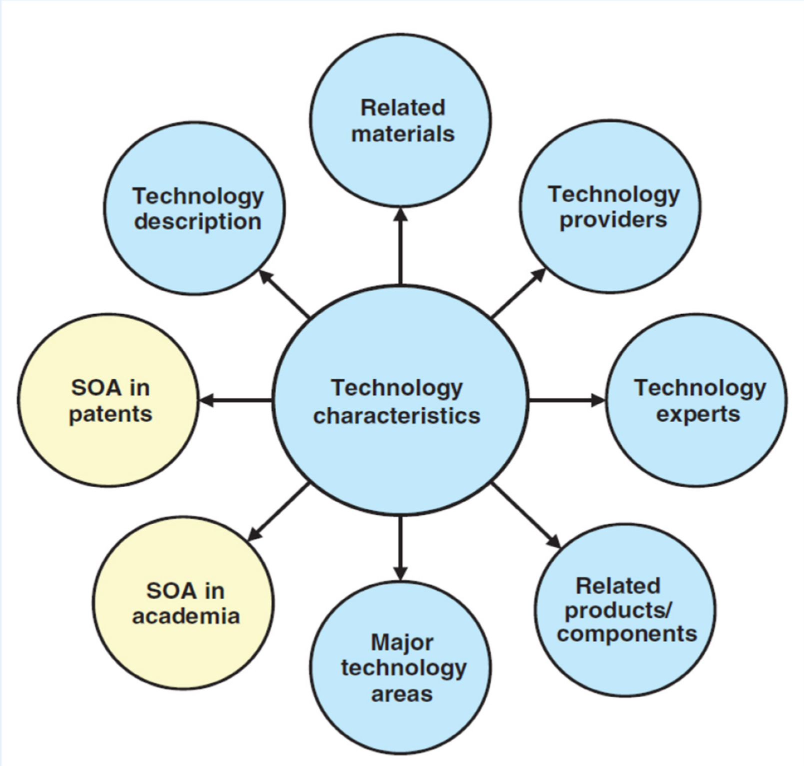

Fig. 13. Examples of technology characteristics according to H. Arman and J. Foden

Source: H. Arman, J. Foden, *Combining methods in the technology intelligence process: application in an aerospace manufacturing firm,* "R&D Management" 2010, no. 40, p. 188, doi.org/10.1111/j.1467–9310.2010.00599.x.

G. Soehadi and co-authors, while conducting an assessment of selected technologies, estimated technological sophistication to determine the level of technology development. In their analysis, they relied on the concept that the determination of the current state of technology is based on the assessment of components in terms of four groups: *technoware* (equipment, office machinery and materials, laboratory equipment, etc.); *humanware* (all the capabilities of employees involved in using *technoware* in the development process); *infoware* and *orgaware*. The components listed by the authors include[106] :

- technology-related operational complexity,
- processing of raw materials,
- control of technological process,
- level of creativity of the employees from technology-related entity,
- ability to work as a team,
- orientation on achievement,
- productivity,
- ability to take risks,
- responsibility,

106 G. Soehadi, L. Setianingrum, S. Rahardjo, I. W. W. Yogantara, E. Purnomo, M. A. Purwoadi, I. Santoso, *Technology content assessment for Indonesia-cable-based tsunameter development strategy using technometrics model*, "Jurnal Sistem dan Manajemen Industri" 2023, no. 7(1), pp. 15–29, doi.org/10.30656/jsmi.v7i1.5748.

- ease of repetition of information,
- ease of networking and communication,
- data processing system,
- speed of access to information,
- effectiveness of leadership in the organization,
- level of commitment,
- level of innovation,
- integrity of operations in the organization.

While the components mentioned in the framework of the conducted research are demanding in terms of their examination in specific organizations and require a very in-depth look at the organization implementing the technology, characterized by broad access to the organization's knowledge, some of them can provide inspiration for operationalizing the technology mapping methodology.

From this perspective, inspiration for a technology card could include: records of machinery and laboratory equipment related to the development of the technology, necessary competencies of people developing the technology, a basic description of how the technology works, raw materials used, level of innovation of the technological solution, and risks associated with the technology. The enterprise card could also address the aspect of competences (with reference to specific competencies, their broader areas or experiences in working with the solution) possessed by the employees of the entity associated with the technology.

Researcher R. O. Zalmout, in developing a methodology for identifying and selecting technologies in the telecommunications industry, emphasized in his research the importance of these activities and the methods used for them in the context of the entire technology management process. As a result of his review of the literature, he considered, among other things, the following to be relevant in his analyses[107] :

- identification of the type of technology and nature of services offered by the entity,
- identification of current and potential application areas for the technology,
- definition of the function of the technology,
- determination of the technical efficiency and cost of the technological solution,
- identification of potential market segments,
- determination of where on the S-curve the technology was located,
- determination of how important it is to implement technology from a business perspective.

107 R. O. Zalmout, *Developing a Methodology for Technology Identification and Selection in Telecommunication Industry (PALTEL as a case study)*, thesis, An-Najah National University, Nablus, Palestine 2013.

In the technology identification and selection model he created, he proposed the following stages in the section relating to identification: conducting technology trend analysis and *technology roadmapping* method, technology monitoring and scanning, competitive analysis, market analysis and telecommunications network analysis. In the various stages of the identification process, the author highlighted the indicators of technology monitoring and analysis, including[108]:

- technology development indicators,
- technological maturity,
- technological attractiveness,
- technology trends,
- market development indicators,
- key players,
- use of technology,
- adaptation of the solution by the market,
- geographic spread.

Within the framework of the second part of the model, relating to technology selection, the author listed among the stages: technology investment analysis, technology assessment, re–identification of technology trends, technology suppliers and technology selection techniques. The first two stages are worth noting here. As part of the investment analysis, the characteristics relevant to the evaluation conducted were[109]:

- technology implementation requirements,
- technology alternatives,
- expected benefits from investing in technology,
- financial and business benefits,
- impact on streamlining operations (e.g., simplifying management, reducing support costs, improving security, increasing productivity),
- potential risks associated with the technology,
- cost implications of implementing technology,
- solution provider's ability to deliver the technology.

In turn, the author considered definition of the technology problem, preparation of a description of the technology, prediction of its future development, identification, analysis and evaluation of the consequences of its implementation, and the communication of the results in a generally accessible form110 as typical elements of technology assessment.

108 R. O. Zalmout, *Developing a Methodology for Technology Identification and Selection ..., op. cit.*

109 R. O. Zalmout, *Developing a Methodology for Technology Identification and Selection ..., op. cit.*

110 R. O. Zalmout, *Developing a Methodology for Technology Identification and Selection ..., op. cit.*

It is worth noting the importance of conducting this type of analysis for the entire technology management process, which is emphasized several times in the work. From the perspective of technology cards for the purpose of technology mapping, listed characteristics of the technology seem to be an important inspiration: description of the technology, current and potential areas of application, functions of the technology, determination of the level of development of the solution or its technological maturity, identification of the key players associated with the technology, geographic spread of the technology, key requirements for the implementation of the solution, alternative technologies, benefits and barriers associated with the implementation of the analyzed solution (in this context, there were also examples of proposals for such benefits as simplification of management, reduction of costs, increased security and/or productivity).

Researchers K. Vishnevskiy and O. Karasev in their analysis focused on foresight in the area of new materials in the field of carbon fiber and analyzed the *technology roadmap* created in this regard. While the use of *technology roadmap* implies an analysis capturing the course of technology development over time, it is worth noting the layers taken into account during its creation. Aspects that appeared in the article include, e.g.[111]:

- major technology trends,
- a description of the advantages and disadvantages of various types of carbon fibers (taking into account the potential wide range of their applications),
- most promising carbon fibers–based materials that can be made,
- reference to market segments where carbon fiber can expand,
- consumer expectations,
- alternative types of new materials,
- technological and economic characteristics of carbon fiber,
- risks, barriers and constraints in carbon fiber development.

Taking into account operationalization of the technology mapping methodology, attention can be paid here to indicating the link between the technology and the final products it is used to produce, areas of application of the technology, advantages and disadvantages of the technology, alternative solutions and their essential advantages, main barriers and limitations to the development of the technology.

111 K. Vishnevskiy, O. Karasev, *Foresight and roadmapping as innovative tools for identifying the future of new materials*, “Maintenance problems” 2014, no. 91(4), pp. 5–14.

As part of a document developed by the U.S. Department of Energy to support analysis of innovative clean energy technologies in advanced manufacturing, an assessment of *Additive Manufacturing* (AM) technologies was presented as part of the 2015 Quadrennial Technology Review (QTR).

Within the framework of the adopted classification of AM processes, a brief presentation was made, taking into account such characteristics as the type of technological process, its brief description, related technologies, and materials used. The draft of the document also featured related entities. The authors, as part of their assessment of the technology and its potential, then described AM applications and challenges, as well as the research and development aspect of the technology. The paper also addressed, among other things, the aspect of risks and uncertainties associated with AM or the impact of AM on policy[112].

An interesting (not so much from a scientific perspective, but from the perspective of disseminating the results of the technology assessment) visualization relating to the analysis of one of the technology's application areas (automotive) was also presented. It used a graphic with a representation of the final product developed by C. A. Giffi, B. Gangula and P. Illinda[113], indicating current and future applications of the technology in relation to the various elements of the product (Figure 14.).

The paper also pointed out that each technology influences many other technologies both in and outside the manufacturing sphere. Some of them may be based on similar research, and there are some solutions (e.g. automation) that have a broad impact on production systems, while others may be used together and complement each other[114].

From the perspective of operationalizing the technology mapping methodology it is important to note such technology characteristics as: current and potential applications with identification of trends or development opportunities, technology risks, identification of technology challenges, organizations playing an important role in terms of technology development, materials used or technology impact. It is also worth noting the aspect of data presentation which, in the opinion of the report's author, is important from the perspective of data presentation in the technology card, and the entrepreneur card, as well as from the perspective of the database of technologies and entrepreneurs. In addition, the important aspect of links between technologies cannot be overlooked.

112 U.S. Department of Energy, *Quadrennial Technology Review. An assessment of energy technologies and research opportunities, Chapter: 6: Innovating Clean Energy Technologies in Advanced Manufacturing, Technology Assessments: Additive Manufacturing*, 2015. Access: www.energy.gov/sites/prod/files/2015/11/f27/QTR2015-6A-Additive%20Manufacturing.pdf [Accessed: 22.07.2023].

113 C. A. Giffi, B. Gangula, and P. Illinda, *3D opportunity in the automotive industry: Additive manufacturing hits the road*, A Deloitte series on additive manufacturing, Deloitte University Press, Westlake (USA) 2014. Access: https://www2.deloitte.com/content/dam/insights/us/articles/additive-manufacturing-3d-opportunity-in-automotive/DUP_707-3D-Opportunity-Auto-Industry_MASTER.pdf [Accessed: 22.07.2023].

114 U.S. Department of Energy, *Quadrennial Technology Review. An assessment ... op.cit*.

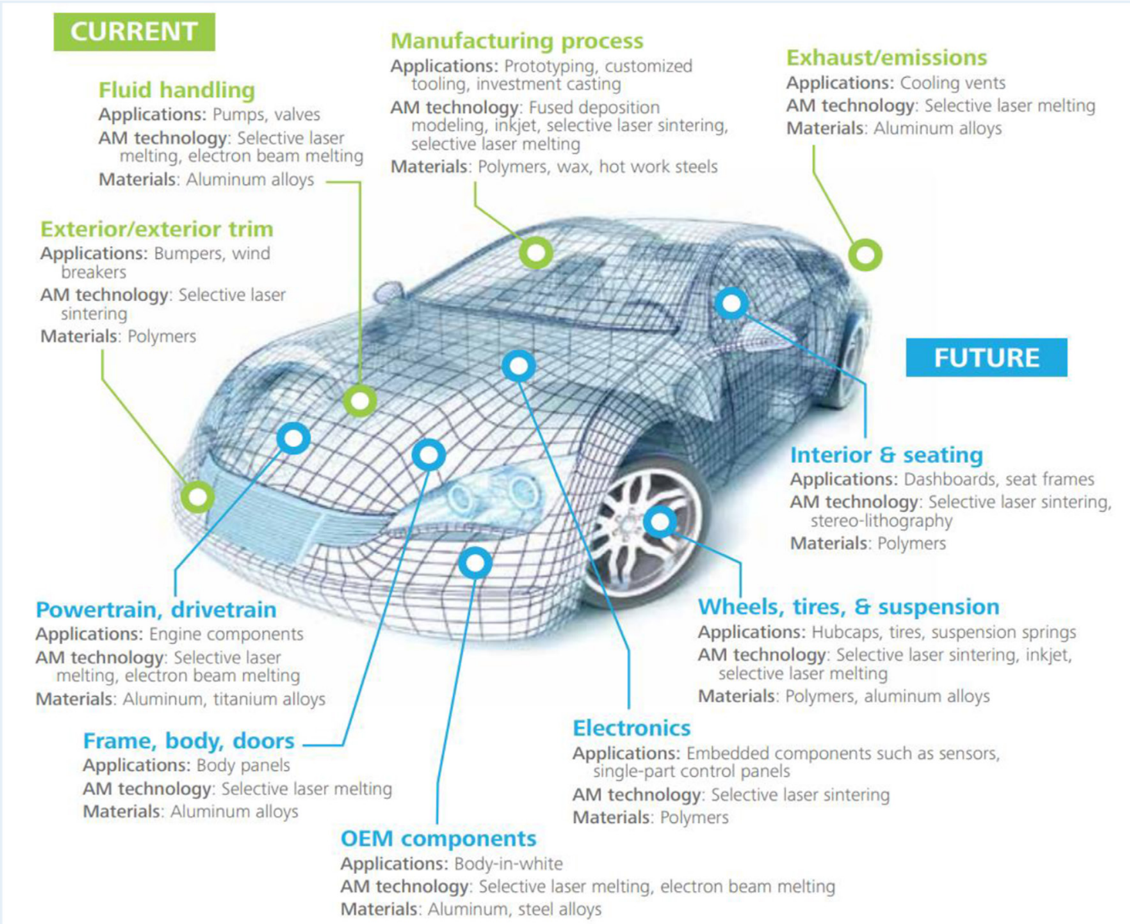

Fig. 14. Example of presentation of technology characteristics: application areas (using the example of the automotive industry and the application of *Additive Manufacturing* technology) developed by Deloitte University Press

Source: C. A. Giffi, B. Gangula, and P. Illinda, *3D opportunity in the automotive industry: Additive manufacturing hits the road*, A Deloitte series on additive manufacturing, Deloitte University Press, Westlake (USA) 2014, p. 13. Access: https://www2.deloitte.com/content/dam/insights/us/articles/additive-manufacturing-3d--opportunity-in-automotive/DUP_707–3D-Opportunity-Auto-Industry_MASTER.pdf [Accessed: 22.07.2023].

Researchers A. Suliman and J. Rankin, developed a technology mapping model (Figure 15.) in their research on technological innovation in the construction industry. Within it, they identified six dimensions for mapping technology–oriented innovation. These dimensions can be divided into framework dimensions (1–4, the last two of which relate to the conditions of the analysis being conducted), as well as innovation dimensions (modeled through dimensions 5–6)[115]:

1. classification to technological area,
2. application areas,
3. time,

115 A. Suliman, J. Rankin, *Maturity-based mapping of technology and method innovation in off-site construction: conceptual frameworks*, “Journal of Information Technology in Construction” 2021, no. 26, pp. 381–408. DOI: 10.36680/j.itcon.2021.021.

4. context,
5. research maturity level (scale: basic research, applied research, evaluation, prototype development, research on industry acceptance),
6. industry acceptance level (scale: a solution characterized by limited acceptance, promising, adapted, implemented, adopted).

From the perspective of technology mapping, the aspect of classifying technologies into groups, indicating applications of technologies, as well as determining their maturity in terms of research maturity and level of industry acceptance seem to be valuable inspirations drawn from the described analyses.

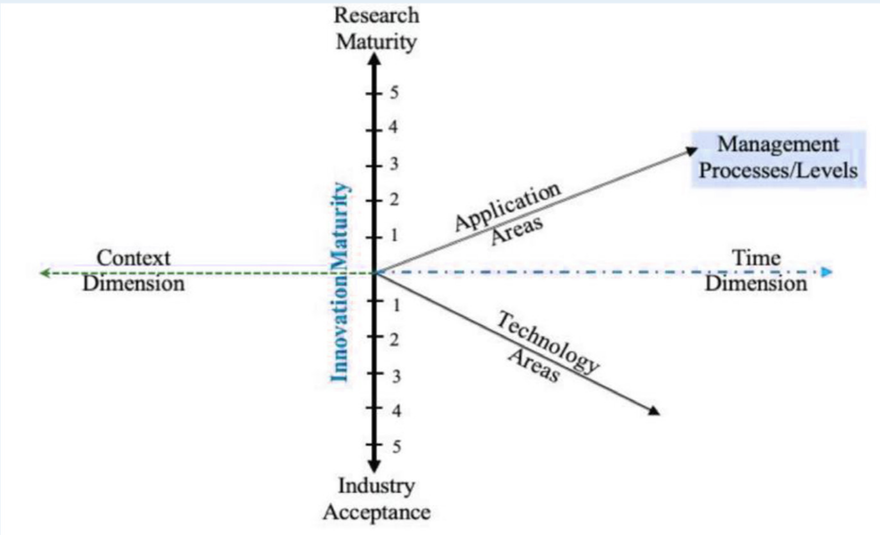

Fig. 15. Technology mapping model according to A. Suliman and J. Rankin

Source: A. Suliman, J. Rankin, *Maturity–based mapping of technology and method innovation in off–site construction: conceptual frameworks*, "Journal of Information Technology in Construction" 2021, no. 26, p. 387. DOI: 10.36680/j.itcon.2021.021.

An interesting analysis in terms of issues relating to educational technology (understood as the use of information and communication technologies to improve the quality of teaching and learning) was conducted by B. Vargas–Quesada, C. Zarco and O. Cordón. Based on a survey of Spanish universities, they identified and then visualized the interdependencies in the group of the analyzed subjects in the form of a network, referred to by the authors as a map of educational technologies.

Figure 16. presents one of the visualizations developed by the authors. The main nodes of the network were the issues mentioned in the survey relating to educational technology, their size represented the level of adaptation in the surveyed universities, and the connections indicated co–occurrence in the universities' areas of interest. Based

on an analogous concept, taking universities as nodes this time, and taking interest in the same educational technology issues as connections, the authors also developed another map[116].

From the perspective of operationalizing the technology mapping methodology, in the light of the discussed publication it seems important to note the possibility of presenting dependencies between different technologies in the form of a network

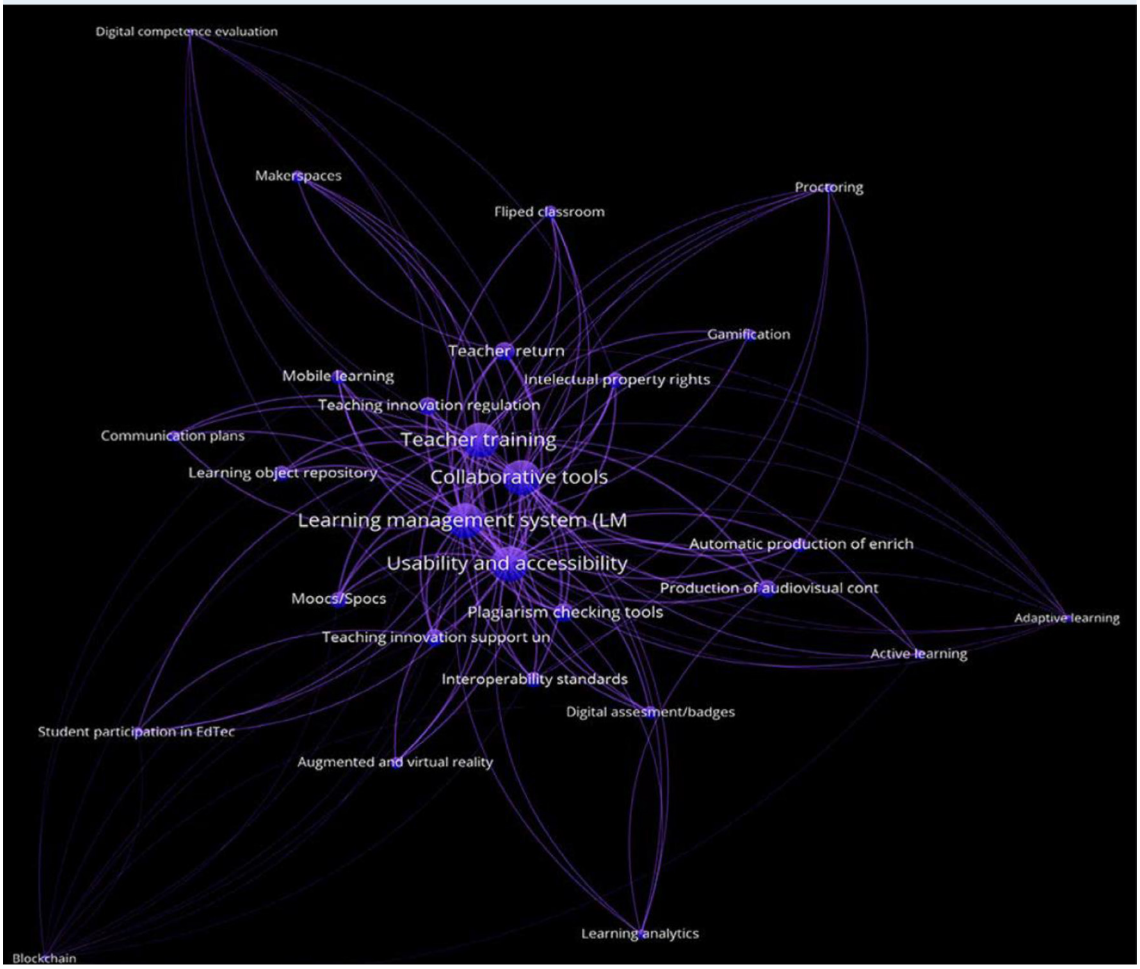

Fig. 16. Example of a technology map according to B. Vargas-Quesada, C. Zarco and O. Cordón

Source: B. Vargas-Quesada, C. Zarco, O. Cordón, *Mapping the Situation of Educational Technologies in the Spanish University System Using Social Network Analysis and Visualization*, "International Journal of Interactive Multimedia and Artificial Intelligence" 2021, no. 8(2), p. 194. DOI: 10.9781/ijimai.2021.09.004.

116 B. Vargas–Quesada, C. Zarco, O. Cordón, *Mapping the Situation of Educational Technologies in the Spanish University System Using Social Network Analysis and Visualization*, "International Journal of Interactive Multimedia and Artificial Intelligence" 2021, no. 8(2), pp. 190–201. DOI: 10.9781/ijimai.2021.09.004.

Researcher I. Spitsberg with co–authors proposed in their research a *Technology Landscape Map* (TLM) as a tool to help capture and more easily communicate the state of knowledge about a specific technological area. The map is intended by its creators to describe the state of technology through the characterization of attributes relating to its essence, maturity and determinants of development. The TLM should therefore present: internal and external technological factors that determine the goals of technology development; key attributes of the technology that are critical to achieving these goals; existing and emerging technologies that exhibit these attributes; maturity levels of these technologies; and the area of potential offered by these technologies. An example of the framework map created as part of the authors' work is presented in Figure 16. Three areas can be seen: technological factors (left side), levels of technological readiness of specific technologies (middle area), spaces of opportunity opened by technologies (right side)[117].

From the perspective of technology mapping methodology, it is worth highlighting technological attributes and functions of technologies that appear within descri-bed analysis, level of technological readiness based on the TRL indicator, as well as the aspect of potential for technology applications.

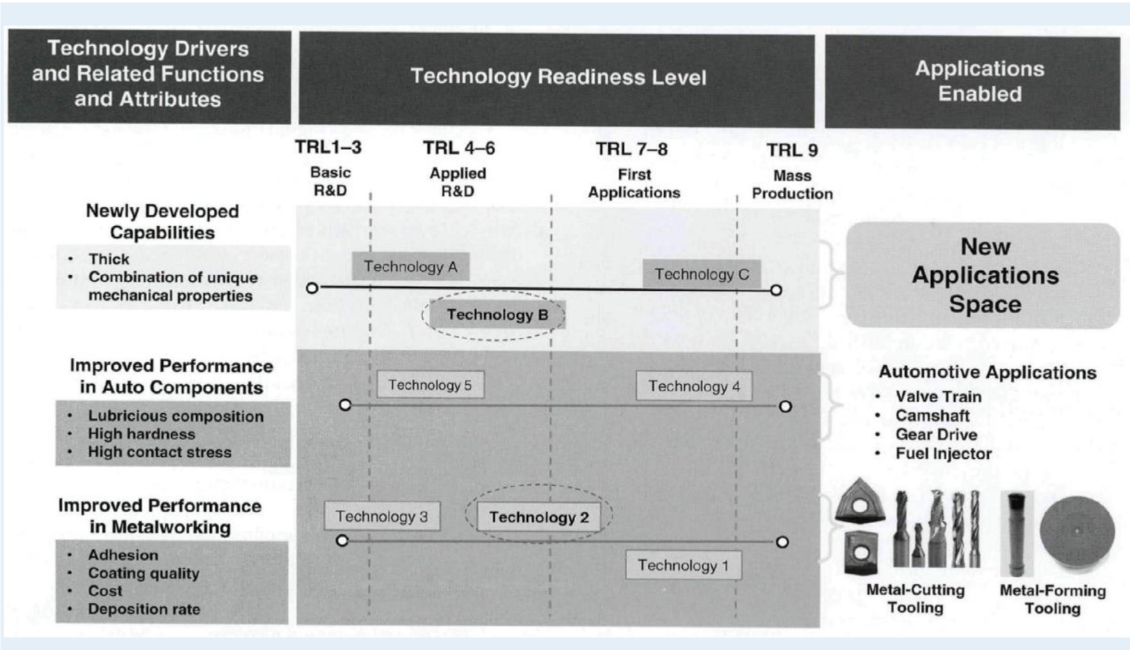

Fig. 17. Example of a technological landscape map according to I. Spitsberg, S. Brahman-dam, M. J. Verti and G. W. Coulston

Source: I. Spitsberg, S. Brahmandam, M. J. Verti, G. W. Coulston, *Technology Landscape Mapping. At the Heart of Open Innovation*, "Research-Technology Management" 2013, no. 56(4), p. 29. DOI: 10.5437/08956308X5604107.

117 I. Spitsberg, S. Brahmandam, M. J. Verti, G. W. Coulston, *Technology Landscape Mapping. At the Heart of Open Innovation*, "Research-Technology Management" 2013, no. 56(4), pp. 27–35. DOI: 10.5437/08956308X5604107.

National Cooperative Highway Research Program report identified, among other things, characteristics of new transportation–related technologies. Here, the authors identified such characteristics as a basic description of the technology, status of its implementation and its challenges, impacts on private travel demand, implications for transportation and land use, impacts on highway/road infrastructure, implications for logistics, policy and planning challenges, and impacts in rural areas. The compiled report devotes a separate chapter to the applications of each of the analyzed technologies[118].

From the perspective of the technology mapping methodology, it is worth noting such characteristics as: description and identification of status of technology implementation, broad impact of the technology, and areas of application.

118 National Cooperative Highway Research Program, *Foreseeing the Impact of Transformational Technologies on Land Use and Transportation*, research report, National Academies of Sciences, Engineering, and Medicine & Transportation Research Board, 2019. Access: https://nap.nationalacademies.org/read/25580/chapter/6 [Accessed: 22.07.2023].

3 Summary

The selected examples described in the report in terms of research and analytical experiments in line with the idea of the technology mapping method provide a number of guidelines, both in terms of implementing the research procedure using this method and in terms of tools that can facilitate the collection and aggregation of data on technologies, and their subsequent aggregate presentation in an easy–to–read form.

It is worth noting that in the aspect of the methodology itself, it was possible to identify quite a number of mentions in the available literature. In contrast, the aspect of tools for collecting and presenting knowledge about technologies and data related to their development and implementation in entities was described to a much lesser extent. In particular, the scope of data collected for the entrepreneurial database can be described as severely limited, often reduced to records of entities and their geographic location. Of the publications the author reached, few addressed the aspect of characteristics of technology–related entities.

The main insights from the literature review that can be considered relevant from the perspective of technology mapping methodology include:

- Determining the current state of technology is an important (and even necessary) stage that should precede any analysis of future technology development, and the use of methods for this purpose increases the reliability of further analysis and decision–making.
- Although the step of analyzing the current state of technology is often implemented, it has just as often found a place in the studies described in the literature, but not in the form of a structured method.
- Technology mapping is one of the methods that propose a structured process to collect and present the broadest possible knowledge base on technologies.
- A good practice for implementing mapping is to create a technology data collection tool dedicated to the group of technologies being analyzed, often referred to as a technology card; technology cards should contain a number of characteristics relating to various aspects of technology development and use, and be collected in the form of a technology database (also made available online).
- It also seems valuable to collect data on entities related to the technology, mainly enterprises (technology producers, suppliers and users) and others, such as, for example: scientific and research centers, research and development centers, technology parks, clusters; these data should be collected in an entity

or enterprise card (depending on the analyzed group), and the cards should eventually feed the database of entities or enterprises; the entity card is a tool analogous to the technology card.

- The two databases (technologies and entities) should be interrelated and allow advanced search and presentation of aggregated data due to selected characteristics of technologies or entities.
- The presentation of data on entities should facilitate the identification of their potential for joint application for funding, knowledge or resource flows, and for the formation of research or technology implementation teams between different entities; the presentation of data should also help identify partners for general cooperation, for expanding networks, or for promoting the technological solutions offered.
- In the author's opinion, it may also be interesting to expand the database of technologies and the database of entities (companies) with a database of experts (technology developers and specialists in their field).
- In the framework of the conducted literature review, it was possible to identify universal characteristics of technologies that can be included in the technology card, but it is important to keep in mind the possibility of expanding the set to include characteristics specific to the group of technologies being analyzed.
- Technologies described with the help of technology cards should be assigned to specific categories, resulting from the specifics of the technologies analyzed and/or classified by function or expert assessment; ready classification proposals can be found in the literature.
- The technology mapping methodology should include an assessment of the level of technology development, which has so far been done using either the technology life cycle concept (often on the S–curve) or the *technology readiness level (*TRL).
- The accumulation of knowledge about technologies often began with the preparation of a basic description of the technology; in some cases, these descriptions were more elaborate, for example, with technical diagrams (intended to explain the operation of the technology more fully), descriptions of the technological process flow or an indication of the components of the technology.
- In terms of data on technologies, it was collected, among other things, on: its basic parameters and functions, the purpose, scope and scale of its use, areas of application (both current and potential, sometimes with examples), and keywords related to the technology.
- In some cases, the technology cards included information on: materials necessary for its use, raw materials (including those that are difficult to access), the time required to implement and/or use the technology, specific conditions of the technological process, and also included the aspect of effects of production/products/services that the use of the technology leads to.

- The technology cards also took into account the aspect of physical resources necessary for its use, e.g., the equipment of the laboratory developing the technology or the hardware or software infrastructure at the company.
- In the technology cards special attention should be paid to the aspect of competencies necessary for the development/implementation/use of technology.
- The following issues were often addressed in technology cards:
  - the advantages and disadvantages of a particular technological solution;
  - benefits and costs of technology development/implementation;
  - impact of technology on the broader environment (highlighted aspects include): ecological, environmental, economic, occupational health and safety, social, ethical, marketing, and the aspect of the degree of social acceptance of a technological solution;
  - risk assessment of the implementation/use of the technology.
- The technology cards also identify determinants and barriers to technology development, both in terms of market and legal conditions.
- Among the characteristics of the technology also appeared the ease of copying or appropriation as well as the ability to protect knowledge of the technology.
- Technology cards sometimes also took into account the aspect of finances related to the technology, especially in the context of the costs to be incurred for its development, implementation and use, and the economic value of the technology.
- The literature has often emphasized the importance of cataloguing companies or, more broadly, technology–related entities in technology cards (these characteristics can be a direct reference to the entities/companies collected in the entity database), the spatial localization of technologies (sometimes distinguishing technology suppliers and points of sale), determining the level of knowledge and/or competence of technology–related entities, or indicating the geographic spread of technologies based on the location of entities.
- Numerous references have been made to records and analysis of patents related to technologies, especially in foreign literature; including many works presenting in–depth analysis in this regard.
- It is also worth noting the link between technologies and scientific and industrial publications, which were also recorded and in some cases analyzed; in this context, there were also studies of the directions of research work related to the technologies analyzed.
- Various technology–related assessments also appeared in the technology card, such as:
  - assessment of the innovation of the solution (the most common assessment);
  - assessment of the level of advancement of technology (for example, closed characteristics: high, medium or low technology);
  - assessment of universality, originality, competitiveness, effectiveness, utilitarianism, functionality, level of complexity;

- assessment of research maturity (on a scale: basic research, applied research, evaluation, prototype development, industry acceptance research);
- assessment of industry acceptance level (on a scale: solution characterized by limited acceptance, promising, adapted, implemented, adopted).

➲ The technology cards also identified alternatives to the analyzed technology, often with identification of its advantages in terms of, e.g., technical or economic advantages or potential to solve specific problems or complement solutions available on the market.

➲ Publications often emphasized the fact of the existence of links between technologies, the occurrence of interactions and the need to recognize them as a system of interrelated elements, the indication of links between them was sometimes supplemented by the determination of the nature of these links, and attempts were made to visualize related technologies in the form of networks created on the basis of developed indicators, the co–occurrence of technologies in certain specific sets, or on the basis of expert assessments or the level of knowledge of specialists in the field of technologies in question.

➲ From the perspective of the analyzed literature, the cards of entities (companies) should include basic information about them, such as:

- geographic location of headquarters;
- territorial scope of activity;
- information on the size and scale of production (in the case of an enterprise),
- cooperation markets;
- possible forms of cooperation between entities;
- the organizational structure relating to technology, the number of employees in technology–related areas or, in the case of a company, the number of production facilities operating for the company (where presenting more detailed information is reasonable and possible given access to data).

➲ Other information of value can also be presented in the entity (enterprise) card, e.g.:

- available machinery;
- general areas of accumulated knowledge related to the technology in the entity/enterprise;
- specific competencies or areas of competence held by the entity's employees;
- past experience in working on technologies;
- activities undertaken in the field of technology management.

➲ The entity (enterprise) card may also indicate the technologies used/developed in the entity; these characteristics, bearing in mind the usability and searchability of the created databases, should be linked to the specific technologies described in the technology cards, specifying how the technology was acquired, the sources of its financing, or the initiators of activities related to the development and implementation of new solutions.

- Publications also featured initiatives pointing out the value of the register of specialists in the technologies in question.
- They also pointed out the importance of the dependencies that exist in a group of actors related to the development of technology, and the identification and visualization of these dependencies (e.g., based on interest in the same technologies).
- As with the technology card, it is possible to find proposals in the literature for possible variants of characteristics for the entity (enterprise) cards.

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Index of drawings

Index of tables

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Technology Mapping – An International Literature Review – this report aims to provide the reader with a definition of the technology mapping method and the basic terminology associated with it. The report also identifies and describes other initiatives, both domestic and foreign, that use technology mapping.
The report was produced as part of the "Technology Mapping in Cluster Enterprises" project conducted by FPPP.

Technology mapping tool:
https://przemyslprzyszlosci.gov.pl/mapowanie-technologii-opis/

Future Industry Platform – foundation established by the Ministry of Development and Technology in order to strengthen the competencies and competitiveness of entities operating on the territory of Poland - entrepreneurs, clusters coordinators, entities working for innovative economy, as well as social and economic partners in the field of digitialization.

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