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Operationalization of the technology mapping methodology for the metalworking sector and a proposal of tools supporting the implementation of the method

Future Industry Platform

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

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1 | Concepts of technology mapping methodology

A review of the literature on technology mapping methodologies[1] has identified a number of experiences relating to both the research procedure carried out using the method and the creation of the tools useful for collecting, organizing and presenting data on technologies collected during the mapping.

It is worth noting that the characteristics of the technologies and entities associated with the technologies are also confirmed by the databases available online. Based on a brief review of the contents of several selected databases the following characteristics relating to the technology were identified: description of the technology/service, advantages/technology benefits, market applications, location of the technology-related entity, form of protection, level of technological readiness/ stage of development, form of commercialization, legal status (through patents related to the technology), keywords, technology application industries, technology problems and solutions, competitive advantages, creators, multimedia/technology-related files.

With regard to technology-related entities the focus was noted on aspects such as: company description, location, contact information, key products, description of products and services offered, implemented technological processes, year of establishment, machinery park, areas of cooperation, experience, multimedia related to the company[2,3,4,5].

It can be noted that while data on technologies was treated somewhat more broadly, data on entities was focused mainly on companies and included a fairly limited body of information. In addition, the data was often presented in the form of separate technology or entity cards without any links between them.

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1 A. E. Gudanowska, *Mapowanie technologii – międzynarodowy przegląd literatury*, report, Future Industry Platform Foundation, November 2023.

2 Website: https://ucitt.amu.edu.pl/dla-biznesu/baza-technologii

3 Website: https://klastermetalowy.radom.pl/czlonkowie/

4 Website: https://www.metalklaster.pl/czlonkowie-klastra/procesy-informatyczne/automatyka-przemyslowa

5 Website: https://ptt.arp.pl/bazy/

Table 1. presents the collected experiences by relating them to the possibility of their use (creation of methodology, technology card, entity card, summary statement), data sources and providing any additional complementary information supporting the use of collected insights in technology mapping methodologies, such as possible variants of characteristics.

In the opinion of the author of the report, it is worthwhile for some of the characteristics (both on the technology as well as entity cards) to use lists of ready responses which were created based on the options identified in the literature.

Adopting such an approach would be particularly useful in case of engaging various respondents (who fill in the content of the database of technologies and entities by sharing their knowledge), as each of them may be characterized by a different understanding of a given characteristic, making possible further coding and aggregate presentation of data more difficult.

On the other hand, this approach deprives the respondent of the opportunity to speak more freely, which is not always desirable.

The concepts collected in Table 1. are the starting point for operationalizing the technology mapping methodology for the purposes of the specific area or industry for which the analysis is done, and the creation of dedicated tools for specific groups of technologies. Thus, the information presented can serve as a starting point not only for operationalizing the methodology for the metalworking sector, but also within other industries.

Table 1. Concepts of technology mapping methodology derived from the literature review

Experience identified in terms of technology mapping	Proposed reference/ possibility ofuse	Data source	Comments
1	2	3	4
Creation of a data collection tool (dedicated to a group of analyzed technologies) often defined as a technology card. Technology cards should be collected in the form of technology database, also made available online.	technology mapping	-	-
Creation of a data collection tool (dedicated to a group of entities related to technology) often defined as an entity card (analogous to technology cards). Entity cards should be collected in the form of a database, also made available online.	technology mapping	-	It is possible to create separate cards for enterprises and other entities, e.g. science and research centers, research and development centers, technology parks, clusters, business incubators, centers for technology transfer.
Creation of a database of experts (developers of technologies, other specialists in relevant fields).	technology mapping	-	-
Technology cards should include universal characteristics independent of the group of analyzed technologies, as well as possible characteristics resulting from the specifics of the analyzed technologies.	technology mapping	-	-
Technologies should be classified into specific areas.	technology card *characteristic: technology classification*	technology experts, literature	⮕ There are many classifications of technologies available in the literature that can be used within this characteristic. ⮕ The adopted classification may simply include groups of analyzed technologies (if they are technologies from different industries) or more general classification, e.g. such as the division into: technology-products; machinery, equipment

Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
			or process technologies; research and test equipment solutions; materials technology and technologies for regeneration and utilization[6]. ⮑ It is also possible to adopt a classification resulting from the specifics of the industry in which the technologies are analyzed.
Technology mapping methodology should include an assessment of technology development level.	technology card *characteristic: level of technology development* collected summary *visualization: technology development levels of technology groups*	technology experts, literature, own analysis	⮑ The possibility of using general levels of development resulting from the phases of the technology life cycle, i.e.: generating ideas (technology idea), implementation (new/emerging technology), application (developmental technology), application development (key technology), maturity (mature technology), disposal (obsolete technology)[7]. ⮑ It is also possible to use S-curve visualization and show the development level on the visualization, also as a proposal for a collective statement for the entire group of technologies. ⮑ A more advanced, expanded scale of technological development based on, e.g., assessment of the level of technological readiness (technology readiness level – TRL)[8] can be used.
Gathering knowledge about technologies often started with creating basic description of the technology.	technology card *characteristic: description of the technology*	technology experts, literature	⮑ *Description of the technology* should be a brief explanation of the basics of the technology operations, possibly with added diagram (if necessary).

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

7 A. E. Gudanowska, *Jak analizować technologie? Wybrane zagadnienia z zakresu metodyki analizy technologii*, [w:] R. Knosala (red.), Innowacje w zarządzaniu i inżynierii produkcji, t. 2, Polskie Towarzystwo Zarządzania Produkcją, Opole 2014, s. 130.

8 J. C. Mankins, *Technology Readiness Levels. A White Paper*, Office of Space Access and Technology NASA, 1995.

Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
	characteristic: course of the technological process *characteristic: technology components*		⮞ *Course of the technological process* may be presented in the block diagram/flowchart. ⮞ *Technology components* are units, subsystems or other technologies included in the technology in question.
Data collected about technologies included e.g.: information on its basic parameters and functions; purpose, scope and scale of its application; areas of use; keywords related to the technology.	technology card *characteristic: basic parameters* *characteristic: purpose of technology use* *characteristic: scale of application* *characteristic: areas of current applications* *characteristic: areas of potential applications* *characteristic: keywords*	technology experts, literature	Scale of application in terms of: units or mass.
Data collected about technologies included information about: materials and raw materials necessary for use of technology, time required for implementation and/or use of technologies, emerging products, specific conditions of the technological process.	technology card *characteristic: materials and raw materials necessary for use of technology* *characteristic: production effects* *characteristic: estimated time for technology implementation* *characteristic: specific conditions of the technological process*	technology experts, literature	⮞ *Materials and raw materials necessary for use of technology* – it's worth marking those that can be difficult to access. ⮞ *Production effects* – products and/ or services resulting from the use of technology.

Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
The aspect of necessary material resources was considered.	technology card *characteristic:* *essential equipment of* *a laboratory developing* *technology* *characteristic:* *infrastructure necessary* *for effective use of* *technology*	technology experts, literature	Both characteristics should include information about both software as well as hardware infrastructure.
Particular attention was paid to the aspect of necessary competences related to technologies.	technology card *characteristic:* *essential competences* *related to usage of* *technology* collected summary *network of competencies* *essential for technology* *development*	technology experts, literature, network analysis based on expert advice	⮥ The competency analysis aspect is very interesting thread that should be included in the technology card (in the form of, at least, a list of essential competencies). ⮥ If a closed list of competencies is used, it would also be possible to create a summary visualization in the form of network of competencies necessary for development/use of a whole group of technologies, e.g. those interesting from the perspective of a database user. ⮥ Individual competencies can be used as the nodes of the network. The links between the nodes may represent the need for particular competency in case of a single technological solution (examples of competency networks can be found in the literature)[9, 10].

9 A. E. Gudanowska, J. Prieto Alonso, A. Törmänen, What competencies are needed in the production industry? The case of the Podlaskie Region, „Engineering Management in Production and Services" 2019, nr 10(1), s.65-74. doi.org/10.1515/emj-2018-0006

10 K. Dębkowska, A. Gudanowska, A. Jurczuk, D1.2. Report on needs and demands for FoF- design: Findings and recommendations Public D1.2. Report on needs and demands for FoF- design: Findings and recommendations, report, Project Title: THE FOF-DE-SIGNER: DIGITAL DESIGN SKILLS FOR FACTORIES OF THE FUTURE, 2019, DOI: 10.13140/RG.2.2.22604.77440.

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Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
Attention was often paid to: the pros and cons of a particular technological solution, benefits and costs of developing and/or implementing technology, impact of technology, risks linked to the implementation and/or use of technology, degree of public acceptance.	technology card *characteristic: benefits of implementing technology characteristic: risks linked to implementing technology characteristic: degree of public acceptance characteristic: impact of technology*	technology experts, literature, evaluations of the levels of impact of technology	⇨ *Degree of public acceptance, risks linked to implementing technology* – evaluated on a predetermined scale (e.g., high, average, low, none) ⇨ *Benefits of implementing technology* – the ability to indicate examples of benefits, such as: simplifying management process, reducing costs, reducing resource consumption, increasing safety and/or productivity, increasing convenience of use, simplifying implementation of selected processes, complementing currently used solutions, solving a significant technical problem in the entity, increasing the attractiveness of the product or service offered, other (what?). ⇨ *Impact of technology* - can be broken down in terms of impact on different areas of the surrounding environment and of selecting impacts interesting from the perspective of purpose of the creation of the technology card and audience of the technology card. It's possible to assess the impact of technology in relation to various aspects such as: ecological, environmental, economic, occupational health and safety, social, ethical, and marketing. Examples of lists of answers relating to selected impacts can be found in the literature[11]. In addition to a text description or a selection from a list, the level of impact can also be assessed.

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[11] A. E. Gudanowska, Technology mapping - an international literature review, report, Future Industry Platform Foundation, November 2023, pp. 26-27.

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Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
Identification of determinants and barriers related to the development of technology.	technology card *characteristic: barriers to technology implementation characteristic: determinants of technology development*	technology experts, literature	*Barriers to technology implementation* – option for using a prepared list of responses, e.g. the nature of barriers to entry scale proposed as a result of the literature review[12].
Collected data also included information about the ease of copying or appropriation of technologies, as well as options for protecting technology knowledge.	technology card *characteristic: level of complexity characteristic: potential for legal protection characteristic: important permits, licenses, formal requirements*	technology experts, literature	➲ *Level of complexity* – ease of copying and/or appropriation of technology assessed by a predetermined scale, e.g. one proposed as a result of the literature review[13]. ➲ *Potential for legal protection* – option for using a prepared list of responses, e.g.: scale proposed as a result of the literature review[14].
Financial aspect related to technology, especially in two contexts: development, implementation and application costs, and economic value of the technology.	technology card *characteristic: estimated costs of technology implementation*	technology experts	-
The importance of cataloguing businesses or, more broadly, entities linked to technologies. Records included identified spatial location of an entity.	technology card *characteristic: entities linked to technology* *visualization: map of country/region with marked location of the entities* collected statements *visualization: technology diffusion map*	technology experts, results of online reviews, data collected from the entities, own analyses	➲ *Entities linked to technology* – this characteristic can be a direct reference to entities/companies collected in the database of entities. In the technology card it can be a list of entities with a possible indication of the level of knowledge or technology competence. A geographical map may be included, with the marked locations of the headquarters of the entities linked to the technology.

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12   Ibid, p. 25.

13   Ibid.

14   Ibid.

Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
			⮊ It is possible to prepare aggregate visualizations showing the geographical diffusion of technology. The map would include an element indicating the number of entities associated with the technology at a particular geographical point.
Numerous references were made to records and analysis of patents related to technologies.	technology card *characteristic: patents related to technology*	technology experts, patent databases	From a literature review perspective, it is valuable to include not only the patent records, but also the bibliometric analyses in this area. Although this type of analysis seems to be the right subject of inquiries in scientific publications, in some cases it may be too advanced for the technology cards.
Links between technology and scientific/industrial publications.	technology card *characteristic: publications related to technology*	technology experts, databases of scientific/ industrial publications	From a literature review perspective, it is valuable to include not only records of publications, but also the bibliometric analyses in this area, which (as in the case of patents) appear to be the proper subject of inquiry in scientific publications. However, in some cases, it may be too advanced for the technology cards.
Selected assessments of Technology.	technology card *characteristic: innovation assessment characteristic: advancement level characteristic: universality assessment characteristics: originality assessment characteristics: competitiveness assessment*	expert assessments	⮊ *Advancement level* – assessed according to the choice of the options, e.g.: high, medium or low advancement level of technology. ⮊ *Innovation assessment, originality assessment, complexity level* – can also be evaluated using a prepared list of answers, e.g. one proposed as a result of the literature review[15].

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[15] A. E. Gudanowska, Technology mapping - an international literature review, report, Future Industry Platform Foundation, November 2023, p. 25..

Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
	characteristics: *effectiveness assessment* *characteristics:* *utilitarianism assessment* *characteristics:* *functionality assessment* *characteristics:* *complexity level* *characteristics:* *research maturity level* *characteristics:* *industry acceptance level* or alternatively, in addition to the above characteristics *visualization:* *radar charts of selected technology evaluations*		⮕ *Research maturity level* – for example rated on a scale: basic research, applied research, evaluation research, prototype development, studies on acceptance in the industry[16]. ⮕ Industry acceptance level – for example rated on a scale: a solution characterized by limited acceptance, promising, adapted, implemented, accepted[17]. ⮕ Selected assessments can be made also using a standardized numerical scale, which makes it possible to present them using a visualization, e.g. a radar chart for a single technology.
Alternative solutions to analyzed technology, often with identification of its advantages, e.g.: technical, economic or in regards of potential to become a solution to specific problems or supplementing solutions already available on the market.	technology card *characteristic:* *alternative technologies* *characteristic:* *distinguishing features of the technology*	technology experts	*Distinguishing features of the technology* – although in this case it seems more valuable to know expert's opinion, it is possible to describe this characteristic with a list of prepared responses using, e.g.: advantages over existing alternatives or the impact of existing alternatives on the market position of technologies on the scale proposed as a result of the literature review[18].
The existence of links between technologies, occurrence of interactions and possible determination of their character, visualization of related technologies (e.g. in the form of network graph).	technology mapping idea technology card *characteristic:* *technological determinants of development* *characteristic:* *directions of technological influences* collected statements *network of mutual interactions* *technology map*	Technology experts, own analyses based on expert opinions about interactions of technologies and entities in terms of usage and/or development of a given technological solutions	⮕ *Technological determinants of development* – other technologies determining the development of technology described in the card. ⮕ *Directions of technological influences* – other technologies whose development is affected bytechnology described in the card.

16   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, nr 26, s. 381-408. DOI: 10.36680/j.itcon.2021.021.

17   Ibid.

18   A. E. Gudanowska, *Technology mapping – an international literature review, report*, Future Industry Platform Foundation, November 2023, p. 25.
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Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
			⮩ Both of the above characteristics may be aimed only at gathering expert knowledge in the context of influences. However, for it to be possible to draw up a summary statement in the form of a network influences/impacts should be contained only in a closed set of technologies collected in the cards. It makes it possible to prepare a visualization in the form of a network graph showing existence of interactions between technologies. It is also possible to diversify connections between nodes presenting the nature of the impacts. ⮩ It is also possible to prepare visualizations in the form of a technology map in relation to co-occurrence of technologies in the area of competencies/knowledge of the entities. In this case individual nodes should represent technologies, and the link between nodes is a co-occurrence within a set of technologies developed/implemented in entities from the database. The greater number of entities in which technology in question is developed/implemented, the more it will be visible on the map. In turn, the strength of the connections will show the strongest clusters forming from technologies co-occurring in entities.
Catalogue of basic information about entities/enterprises.	Entity/businesses card *characteristic:* *location* *characteristic:* *territorial coverage of activities* *characteristic:* *size and scale of production (in the case of enterprises)* *characteristic:* *possible areas and forms of cooperation*	entities/businesses	⮩ Entity cards can be separated into two groups: enterprise cards and cards of other entities. The cards would have the same form, and the scope would be limited only in the case of entities other than companies.

Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
			➲ *Possible areas and forms of cooperation* – data can be gathered from declarations of the entities or by picking an answer from a prepared list regarding possible areas of cooperation in technology management: the idea behind emergence of technology, development of concepts about new technology, identification of technology, technology selection, sourcing/acquisition of technology, exploitation of technology, protection of technology, development of technology, exploration of new areas of application of technology, implementation of technology in the industry, conducting educational activities (e.g. courses, training), dissemination of technology on the market, organization of work, organization of study visits to enterprises, subsidizing participation in trade fairs, joint shopping, other[19].
Information on: available machinery, general areas of knowledge relating to the technology that is gathered in the entities/enterprises, specific competencies or areas of expertise held by employees of the entity, experiences in terms of working on technologies or actions taken in terms of technology management.	Entity/ business card *characteristic: available machinery characteristic: competencies and experiences* collected summary *network of competencies in the cluster/group of entities*	entities/ enterprises, network analysis based on declarations of entities	➲ *Competencies and experiences* – in the case of use of a closed list, it would be possible (as in the case of competencies needed for the development of technology) to create an aggregate visualization in the form of a network graph of competencies held by entities registered in the database. Competencies should be taken as nodes of the network. Links between competencies – having them in the case of a single entity. ➲ It is possible to use ready-made lists of competencies available in the literature, e.g.:[20]

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

20   Dębkowska, K., Godlewska, J., Olszewska, A. M.,Tomaszuk, A., Tomaszewska, E. J., Widelska, U., *Potrzeby pracodawców w zakresie wsparcia w kształceniu ustawicznym w zawodach deficytowych w województwie podlaskim*, Wojewódzki Urząd Pracy w Białymstoku 2017, Białystok.

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Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
			technical skills, professional knowledge, foreign language skills, strategic thinking, conscientiousness/reliability, orientation on customer, analytical thinking, procedures – knowledge and application, planning, professional development/readiness to learn, independence, team building skills, striving for results (entrepreneurship), IT skills, problem solving skills, business orientation, teamwork/collaboration in a team, communication skills, innovation and flexibility, negotiating skills, administration/managing documentation, building an efficient organization, conflict resolution, motivation, process management, decision making, team management, knowledge and experience sharing, project management, leadership skills, identification with the company, internal cooperation, self-management, delegation, exerting influence, building relationships.
Technologies used/developed in the entity, as well as methods of sourcing technologies, sources of funding, initiators of activities related to creation and implementation of new solutions.	Entity/business card *characteristic: technologies owned characteristic: existing ways of obtaining technology characteristic: sources of funding characteristics: initiators of technology*	entities/enterprises	⊃ *Technologies owned* – characteristic should be linked to specific technologies described in the technology cards. ⊃ *Existing ways of obtaining technology* – the following list of answers may be used: technologies made available through cooperation with enterprises, effects of cooperation with a research and development unit, modernization of the "obsolete" technologies to fit new needs of the enterprises, technologies developed and manufactured at the company, and the purchase of technology[21].

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

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Table 1. cont. Concepts of technology mapping methodology derived from the literature review

1	2	3	4
			➲ *Sources of funding* – the following list of answers may be used: own resources of businesses, leasing, bank credit, lease/rental use of machinery/ equipment, using public funds to support the economic activities of entities (e.g. national budget funds, European Union funds)[22]. ➲ Initiators of technology – the following list of answers may be used: Management, Director/Chief Development Officer, Director/Head of Technology Department, Employees, Project team, clients, needs arising from the market/ market niche, market trends, owners of the enterprises, other[23].
Identification and visualization of dependencies occurring in the group of entities linked to the development of technology.	collected summary *network of entities*	network analysis based on declarations of entities	It is possible to prepare an aggregate visualization based on the declarations of entities collected within characteristic *"owned technologies"*. Visualization in the form of a network graph of entities can take individual entities as nodes, and for links interest in the same technology. Such visualization would highlight the potential for cooperation between enterprises in terms of the technologies possessed by entities.
Catalogue of specialists/experts in the field of particular technology.	technology card *characteristic: key experts*	technology experts, entities/ businesses	-
Key products/ offers/descriptions of offered products and services.	entity business card *characteristic: key products and/or services*	entities/ businesses	-

Source: own compilation based on literature review.

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22 Ibid.

23 Ibid.

2 | Operationalization of the technology mapping methodology for the metalworking sector

The concepts of the technology mapping methodology presented in the previous chapter are a translation of the conclusions reached in the literature review presented in a separate report[24] into practical recommendations for technology mapping methodology. It's a fairly comprehensive set that can provide a starting material for operationalizing the general mapping methodology and creating dedicated tools targeted to specific project needs.

Figure 1. shows the operationalized technology mapping methodology developed for the metal industry. The next chapter presents a proposal for dedicated tools.
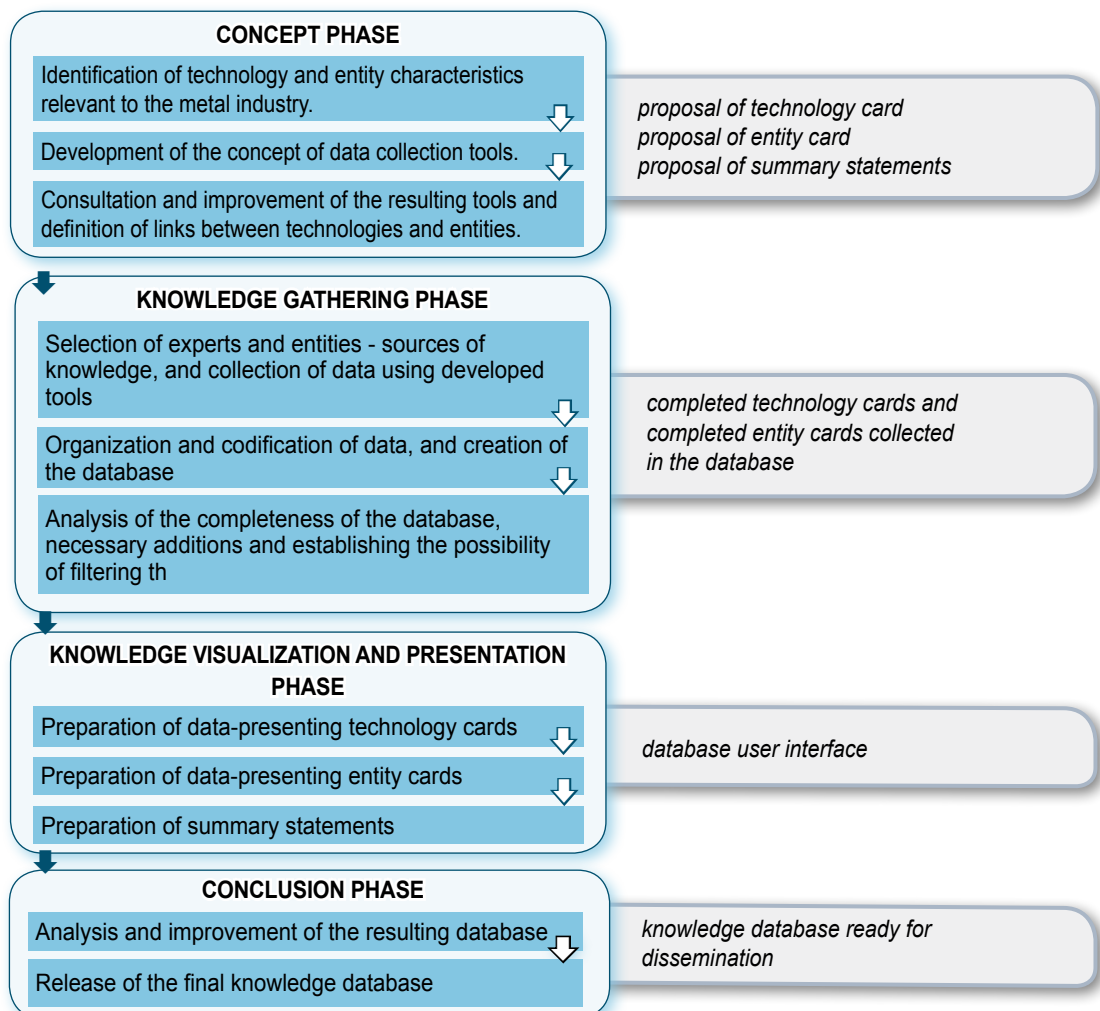
CONCEPT PHASE

Identification of technology and entity characteristics relevant to the metal industry.

Development of the concept of data collection tools.

Consultation and improvement of the resulting tools and definition of links between technologies and entities.

proposal of technology card
proposal of entity card
proposal of summary statements

KNOWLEDGE GATHERING PHASE

Selection of experts and entities - sources of knowledge, and collection of data using developed tools

Organization and codification of data, and creation of the database

Analysis of the completeness of the database, necessary additions and establishing the possibility of filtering th

completed technology cards and completed entity cards collected in the database

KNOWLEDGE VISUALIZATION AND PRESENTATION PHASE

Preparation of data-presenting technology cards

Preparation of data-presenting entity cards

Preparation of summary statements

database user interface

CONCLUSION PHASE

Analysis and improvement of the resulting database

Release of the final knowledge database

knowledge database ready for dissemination

Fig. 1. Operationalized technology mapping methodology for the metalworking industry

24 A. E. Gudanowska, *Technology mapping – an international literature review*, report, Future Industry Platform Foundation, November 2023.

The developed technology mapping methodology consists of four phases: conceptualization, knowledge gathering, visualization and presentation of knowledge, conclusions. Each phase identifies the activities to be performed and indicates the effects that should result from their implementation.

1 In the concept phase, identification of the characteristics of the technology and the entities useful in the study of the metal industry should be carried out. The development of concepts for data collection tools should also take place during this phase. The effects of these activities are described in this report.
The next activity in the concept phase is conducting consultation on the subject of the resulting tools, leading to their updates, such as supplementing the set of chosen characteristics with any additional characteristics resulting from the specifics of the analyzed industry. The last activity of the concept phase should be defining possible links (both within the group of analyzed technologies, as well as entities) that will be considered in further work. The phase should result in a final proposals of technology card, entity card and summary statements.

2 In the knowledge gathering phase, a selection of experts and entities that will provide relevant, necessary knowledge should take place. Next step should be data collection process using the developed tools. Collected information will then be organized, some of it will be codified for the purposes of appropriate presentation of data, and the creation of a database will take place. The database should then be analyzed for completeness and supplemented if necessary, e.g. by using specialized literature on the subject. At this stage of the work the final filtering capabilities of the database should also be established. Results of this phase should include technology and entity cards filled-in with relevant information.

3 As part the visualization and presentation of knowledge phase summary statements presenting structured and aggregated data should be prepared. The database, as well as technology and entity cards, should be completed, including creating user-friendly interface and graphic design

4 In the conclusion phase, analyses and improvements to the database should be carried out by conducting tests of its operations. The knowledge database, ready for dissemination, should be made available online.

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3 Proposal of tools for data collection and presentation for technology mapping methodology in the metalworking sector

3.1 Technology card

One of the tools for collecting and presenting data in the technology mapping methodology dedicated to metalworking industry is the technology card. Table 2. shows the proposed scope of the technology card by indicating the characteristics to be included in the card, along with lists of possible answers to simplify the process of completing the cards, as well as expand the filtering capabilities of the technology database. In addition, the table indicates, what type should each variable representing a characteristic in the database be and whether it is associated with another variable.

Table 2. Technology card for technology mapping in the metalworking industry

Technology characteristic	List of possible answers	Type of variable representing characteristic in the database and possible links
1	2	3
technology classification[25]	➲ machining ➲ forming ➲ heat treatment ➲ chemical processing ➲ surface treatment ➲ assembly/disassembly technologies ➲ advanced automation technologies ➲ enabling technologies	dictionary variable (single selection)
level of technology development	Evaluation according to the technological readiness level indicator (technology readiness level – TRL)[26, 27]:	dictionary variable (single selection)

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

26 J. C. Mankins, *Technology Readiness Levels. A White Paper*, NASA Office of Space Access and Technology, 1995.

27 K. Santarek (red.), *Transfer technologii z uczelni do biznesu. Tworzenie mechanizmów transferu technologii, PARP*, Warszawa 2008, s. 88.

Table 2. cont. Technology card for technology mapping in the metalworking industry

1	2	3
	PHASE I (RESEARCH AND DEVELOPMENT): ⮑ Level 1 – observing and noting basic rules ⮑ Level 2 – formulation of the concept and/or application of the technology ⮑ Level 3 – analytical and experimental confirmation of key technology functions and/or concepts PHASE II (TESTING AND DEMONSTRATION): ⮑ Level 4 – verification of components and/or models under laboratory conditions ⮑ Level 5 – verification of components and/or models under conditions similar to real environment ⮑ Level 6 – construction of a system/subsystem models or prototypes under conditions close to real environment ⮑ Level 7 – demonstration of the technology prototype in operational environment PHASE III (IMPLEMENTATION AND DEPLOYMENT): ⮑ Level 8 – implementation of the target system/product in operational environment ⮑ Level 9 – technology proven in real-world conditions	
description of technology	-	text variable, possibility of including graphics
technology components (understood as units, subsystems or other technologies included as parts of the technology in question)	-	text variable
keywords related to technology	-	text variable
scale of technology application	⮑ unit ⮑ mass	dictionary variable (single selection)
current applications of technology	-	text variable
materials and raw materials necessary for use of technology (indicating those that are difficult to access)	-	text variable
production effects (products and/or services resulting from use of technology)		text variable

Table 2. cont. Technology card for technology mapping in the metalworking industry

1	2	3
estimated time of implementing technology	-	text variable
specific considerations of technology process (if such exist)	-	text variable
laboratory equipment essential for technology development (hardware infrastructure and software)	-	text variable
infrastructure essential for effective use of technology (hardware infrastructure and software)	-	text variable
competencies essential to use of technologies[28]	-	text variable[29]
benefits of implementing technology	⮑ simplifying management processes ⮑ costs reduction ⮑ reduction in resource consumption ⮑ security increase ⮑ productivity increase ⮑ increase in user convenience ⮑ increase in simplicity of implementation of selected processes ⮑ complementing the solutions currently in use ⮑ solving a significant technical problem ⮑ increasing the attractiveness of the offered product or service ⮑ other (what?)	dictionary variable (multiple choice with the possibility of additional answers)
level of social acceptance	⮑ high ⮑ average ⮑ low ⮑ lack of acceptance	dictionary variable (single selection)
impact of technology diffusion in the socio-ethical context	⮑ impact on the creation of new jobs ⮑ impact on the development of the national industry ⮑ benefits to human health and quality of human life ⮑ aesthetic benefits (e.g., scenic or olfactory qualities)	dictionary variable (multiple choice with the possibility of additional answers)

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28   It would be valuable to include a ready-made set of competencies developed by experts directly for the metalworking industry – sets available in the literature may represent an approach that is too broad and generalized. It would then be possible to draw up summary statements, as well as provide a list of responses that would ultimately allow filtering of the technology database in terms of required competencies.

29   When conducting a reconnaissance on competencies in the metalworking industry - a dictionary variable (multiple choice).

Table 2. cont. Technology card for technology mapping in the metalworking industry

1	2	3
	➲ benefits in terms of improving the image of the national economy ➲ benefits in terms of creating an industry standard ➲ source of social problems ➲ can directly lead to violations of commonly ➲ applicable moral norms or laws ➲ source of problems for human health or quality of human life ➲ can be a source of aesthetic problems (related to, e.g. landscape or olfactory nuisances) ➲ can be a source of privacy problems for potential users or others ➲ source of problems concerning applications of the principles of social justice, in areas of e.g. discrimination, inequality ➲ compliance with country's policies (including innovation, ecological, and regional development policies), in particular their objectives and priority areas ➲ other (what?)	
impact of technology diffusion in the ecological context	➲ can provide tangible benefits in terms of increasing the level of safety in the industry ➲ can be a source of environmental problems ➲ manufacturing of the technology or a product based on it can be seen as 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 inefficient use of energy in manufacturing, use or disposal process ➲ manufacturing of the technology or a product based on it can be seen as a source of environmentally burdensome emissions ➲ and waste in 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 failures or accidents occurring during the manufacturing, use or disposal process	dictionary variable (multiple choice with the possibility of additional answers)

Table 2. cont. Technology card for technology mapping in the metalworking industry

1	2	3
	➲ manufacturing of the technology or a product based on it requires 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 ➲ savings of natural resources (including water) compared to previously used alternatives ➲ manufacturing of the technology or a product based on it will contribute to energy savings compared to the previously used alternatives ➲ manufacturing of the technology or a product based on it will contribute to the reduction of environmentally burdensome emissions and waste compared to the previously used alternatives ➲ manufacturing of the technology or a product based on it will contribute to the ➲ reduction of the risk of accidents or emergencies compared to the previously used alternatives ➲ manufacturing of the technology or a product based on it will contribute to the ➲ reduction of amount of the hazardous substances used in the manufacturing, use or disposal process compared to previously used alternatives ➲ manufacturing of the technology or a product based on it will allow the use of secondary raw materials in the manufacturing, use or disposal process ➲ other (what?)	
barriers to implementation of technology	➲ very high barriers to entry, based on (among other things) difficult access to (unique) materials or components ➲ high barriers to entry, based on (among other things) patent protection ➲ medium barriers to entry, based on (among other things) exclusive license agreements with suppliers of key components ➲ low barriers to entry ➲ direct competitors already exist and offer comparable solutions	dictionary variable (single selection)
determinants of development	-	text variable

Table 2. cont. Technology card for technology mapping in the metalworking industry

1	2	3
level of complexity	➲ a very high degree of complexity, making it impossible to copy technology even after taking possession of a copy of the solution and subjecting it to reverse engineering ➲ high degree of complication, making it impossible to copy the technology based on testing the solution and reading the technical documentation/user manual ➲ medium degree of complication, allowing the technology to be copied by observing the solution ➲ low level of complication, allowing the technology to be copied by reading materials promoting the solution or learning about the the basic principles of operation; the technology is very simple and can be copied by observation	dictionary variable (single selection)
potential for legal protection	➲ full patent protection ➲ limited patent protection ➲ by way of confidentiality, protection of know-how and protection of documentation under copyright law ➲ protection is no longer possible	dictionary variable (single selection)
key permits, licenses, formal requirements	-	text variable
estimated costs of implementing technology	-	text variable
entities linked to technology	-	list of entities **linked to the database of entities**[30], graphic presentation: map (country/region) with geographical location of entities
patents related to technology	-	text variable
publications related to technology	-	text variable

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[30] It is worth bearing in mind that, within this characterization, there may be a situation where uncharacterized entities appear in the entity database.

Table 2. cont. Technology card for technology mapping in the metalworking industry

1	2	3
originality assessment	➲ breakthrough innovation on the world scale ➲ a nationally innovative solution, but one that has foreign equivalents ➲ innovative solution in the industry/application area, that has counterparts in other industries/areas ➲ a solution that is hardly original, similar to existing solutions used on the scale of industry/area of application	dictionary variable (single selection)
alternative technologies	-	text variable
distinguishing features of the technology (advantages with regards to alternative solutions)	-	text variable
key experts	-	text variable
technological determinants of development (other technologies determining development of technology described in the card)	-	text variable
directions of technological influences (other technologies whose development is affected by technology described in the card)	-	text variable

Source: own compilation based on literature review.

4 | Entity (company) card

Another proposed tool for mapping technology in the metalworking industry is the entity (enterprise) card. Depending on the decisions made during consultations with industry companies, the card will include either only companies or a broader group that also includes other entities with their contribution to technology development. If a broader group of entities is included, some of the cards (not related to the enterprises) may be limited in scope.

Table 3. Entity (company) card for technology mapping in the metalworking industry

Characteristic of technology	List of possible answers	Type of variable representing characteristic in the database and possible links
1	2	3
location	-	text variable, graphic presentation: map (country/region) with the geographic location of the entity
status of entity[31]	➲ enterprise ➲ other (what?)	dictionary variable (single selection with the possibility of giving additional responses)
volume and scale of production	-	text variable (appearing only for enterprises – status: enterprise)
key products and/or services	-	text variable, possibility of adding multimedia (appearing only for enterprises– status: enterprise)
purpose and character of the activity	-	text variable, possibility of adding multimedia (appearing only for other entities – status: other)
possible areas and forms of cooperation	➲ the idea behind the creation of the technology ➲ development of concepts of the new technology ➲ technology identification ➲ technology selection/choice ➲ technology sourcing/acquisition ➲ operation of technology ➲ technology protection	dictionary variable (multiple choice with the possibility of giving additional responses)

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31 Characteristics appearing only if the base is expanded to include entities other than companies.

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Table 3. cont. Entity (company) card for technology mapping in the metalworking industry

1	2	3
	➲ technology development ➲ seeking new areas of technology application ➲ implementation of technology in the industry ➲ conducting educational activities (e.g. courses, training) ➲ sharing of machinery park ➲ dissemination of technology on the market ➲ organization of work ➲ organization of study visits to enterprises ➲ subsidizing participation in trade fairs ➲ joint purchases ➲ other (what?)	
machinery park	-	text variable
competencies and experiences[32]	-	text variable
owned technologies	-	list of **technologies linked to a technology database**[33]
current ways of technology acquisition	➲ technologies made available through cooperation ➲ with companies ➲ results of cooperation with the research and develop-ment unit ➲ upgrading "obsolete" technologies to fit new needs of the business ➲ technologies developed and produced by the com-pany ➲ purchase of technology ➲ other (what?)	dictionary variable (multiple choice with the possibility of giving additional responses)
current sources of financing	➲ company's own funds ➲ lease ➲ bank loan ➲ lease/rental use of machinery/equipment ➲ using public funds to support the economic activities of entities (e.g. national budget funds, European Union funds) ➲ other (what?)	dictionary variable (multiple choice with the possibility of giving additional responses)

Source: own compilation based on literature review.

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32 Analogous to technology card, it is possible to rely on a set of competencies relevant to the metalworking industry developed for the creation of the databases.

33 It is worth bearing in mind that, within this characterization, there may be a situation where uncharacterized entities appear in the entity database.

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5 | Additional comments

It is important that the databases and entities contain comprehensive data sets and allow for a variety of filters, so that recipients can make their own selection of information important to them (relating both to technology, as well as entities) and use them for further analysis.

As part of technology mapping for the metalworking industry, in addition to the ability to filter the database and display the results depending on the selected states of the closed characteristics (individual elements with list of pre-prepared responses), it is also possible to develop summary statements of the collected information, and then present them within the database:

- ⊃ a summary showing the level of development of all technologies collected in the database (according to the TRL scale) – it can take the form of a simple graphic with 9 levels and icons denoting the various technologies applied to scale (general summary);

- ⊃ a visualization showing the diffusion of the technology in a given geographic area (country/region) – graphic elements should appear on the map with their size indicating the number of entities connected with technology in a given geographic area (summary both for single technology and capturing (in general) all technologies from the database).

In the works analyzed in the literature review, great attention was paid to bibliometric analyses, especially in the context of analyzing patents or scientific publications related to technologies. While creating a catalogue of some patents and scientific publications is always possible, conducting a more in-depth analysis can be a difficult task in the context of a database. For example, analyses capturing the network presentation of links between patents or publications relating to the co-occurrence of e.g. keywords that characterize them, can require the creation or use of other, more complex tools than those for filtering and displaying data collected in the database.

A similar situation can be seen in the case of the network of competencies necessary for the development of technology, technology map (and therefore networks of technology interactions) or networks of competencies held by a group of entities. Their creation would require additional network analysis, and then presenting the finished results in the form of downloadable graphics.

From the perspective of increasing the attractiveness of the database to the public, in addition to the aforementioned substantive analyses and related visualizations, an interesting idea would be to show the final product(s) of a given industry and possibly their related technologies or their applications. Such visualization used as a starting page of the technology database could simultaneously be a collection of hyperlinks to specific technology cards. However, it is a solution possible only when mapped technologies are closely related to specific products.

The two databases - both of technologies and entities - should be linked to each other, as indicated in the proposed cards. Links should allow the user to quickly navigate to the card of a specific technology or specific entity by selecting the name of the technology/entity.

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Operationalization of the technology mapping methodology for the metalworking sector and a proposal of tools supporting the implementation of the method – This report aims to present technology mapping as one of the methods that allows study, cataloguing and analysis of the connections between entities operating within the Polish economy. The publication presents both general concepts, as well as tips for adapting the process of technology mapping to the specifics of a particular industry. The report was created as part of the project "Technology mapping in cluster enterprises" 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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