Identify new application fields of a given technology

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Abstract. The economic crisis caused by the closure of businesses forced many companies to review their business model and rethink their product catalogue. To achieve this, they need help to identify new forms of transfer of their technologies and knowledge towards new products. In this conference paper, the authors propose a methodology conceived as a tool to support start-ups, long before Covid-19 came along, and which is currently undergoing an important acceleration process to quickly respond to the demand of small and medium-sized companies. The objective of the proposed methodology is to analyze a given technology and to understand possible alternative fields of application to the starting one. For each new potential area there is a complex evaluation that tries to position the product according to technical and economic parameters. At the basis of the methodology there are the most modern tools of Information Retrieval: SAO (Subject Action Object) triads and algorithmic approaches based on patterns recognition. The combination of these two approaches, no antithetical to each other, forms the basis of the methodological proposal of this paper. They are used to automatically analyze large patent pools and extract features of technological nature such as functions, product requirements and fields of application. Once the list of potential fields has been extracted, it is possible to assess the potential impact and investment risk by introducing other key tools developed by the TRIZ community, such as market potential. In order to make the methodological process more fluid, specific indicators have been created, such as the Transfer Potential, which indicates the replacement potential of a new technology compared to an old one. The proposed approach is tested through an explanatory industrial case study.

Keywords: TRIZ, Technology Transfer Outward, Natural Language Process, Functional Search, Semantic Dependency Patters, Market Potential, Patents

1 Introduction

The economic crisis caused by the closure of businesses by the collapse of consumption has forced many companies to review their business model and rethink their product catalogue. From one day to another, there was a collapse in sales of certain products, such as, for instance: small domestic appliances and consumer electronics.

For this reason, the demand from companies for technological positioning services has increased. To achieve this, they need help to identify new forms of transfer of their technologies and knowledge towards new products. This process is called Outward Technology Transfer [1], and it differs from the Inward Technology Transfer in which external technologies (often emerging and licensed) are acquired for the development of new products [2].

For Inward Technology Transfer the TRIZ world has proven to be very prolific. From the Altshuller pointers to physical effects [3] approaches and methodologies have emerged that help inventors to find alternatives at the level of operating principles and physical effects: for instance, Tech optimizer [4], Aulive [5], Oxford creativity [6], Russo's Tech Transfer [7]. Unfortunately, we cannot state the same for Outward Technology Transfer.

In this conference paper, the authors propose a methodology they have been working on for a long time, conceived as a tool to support start-ups, long before Covid-19 came along, and which is currently undergoing an important acceleration process to quickly respond to the demand of small and medium-sized companies.

The objective of the proposed methodology is to analyze a given technology and to understand possible alternative fields of application to the starting one. For each new potential area there is a complex evaluation that tries to position the product according to technical and economic parameters. At the basis of the methodology there are the most modern tools of IR, Information Retrieval.

In recent years, we have witnessed a continuous and powerful growth of these tools, especially those capable of automatically recognizing specific features through artificial intelligence training. Since the first attempts of the SAO (Subject Action Object) triads [8] with Goldfire Innovator, [patent WO2010/105214], even algorithmic approaches based on patterns recognition have made significant improvements: from the works of INSA – Strasbourg [9] and University of Pisa [10] to the ones of University of Bergamo [11]. The objectives of the previous mentioned approaches, differently from SAO triads search, concern the improvement of the extraction of technical information from the text of documentary sources in a systematic way. The contributions just mentioned are just a few of the TRIZ world.

The combination of these two approaches, which are by no means antithetical to each other, forms the basis of the methodological proposal of this paper. They are in fact used to automatically analyze large patent pools and extract features of technological nature such as functions, product requirements and fields of application.

The paper describes in detail the series of steps by which these tools are used to facilitate the analyst's work. Once the list of potential fields of application has been extracted, it is possible to assess the potential impact and investment risk by introducing other key tools fundamentals developed by the TRIZ community, such as market potential, into the methodology [12; 13]. In order to make the methodological process more fluid, specific indicators have been created, such as the Transfer Potential, aimed at assessing the replacement potential of a technology deemed to be alternative. The higher the value of the Transfer Potential, the more affordable is the replacement. In addition, the main economic and market indexes were analyzed in detail to offer the company the minimum set of measurements necessary for an informed choice minimizing risks.

Finally, the language was also taken care of, how to communicate the output with simple diagrams such as the technology substitution graph. To date, the methodology has only been tested on three case studies, but the positive feedback we have received from financial intermediaries and company owners encourages us to continue automating this approach and solving the many problems that still remain open and for which commitment and perseverance are required.

A fundamental contribution to this activity has been made by TRIx srl, a start-up from the University of Bergamo, which has developed a software infrastructure capable of automating many of the processes stated here and gradually anticipated in scientific articles already published (computers in industry) or submitted to sector journals (Journal of Engineering and Technology Management).

The proposed approach is tested through an explanatory industrial case study. The article presents an overview of function search based and TRIZ market potential techniques in section 2. Section 3 illustrates the proposal and the methodological steps conducted during the study. Afterwards, in section 4, the application of the methodology through a case study is provided and, in the end, section 5, draws the conclusions and the future developments of the work.

2 Background

2.1 Function search based

In this section, the main methods of Function search based and the contribution of Outward Technology Transfer are discussed. Concerning OTT, the contributions in the state of the art have in common the exploitation of patent database [14]. The methods and tools for analyzing intellectual property database includes AI methods, for instance machine or deep learning approaches adopted for very far and different purposes [15]. To cite a few examples relevant to the research of this paper: knowledge and technological management of information [15]. Contaminations with different many other methods, such as functional analysis [16], or Function Behavior Structure (FBS) techniques [10]. Other examples consider the methods that uses NLP instruments by extracting technology opportunity discovery [17]. At the basis of the methodology there are the most modern tools of IR, Information Retrieval, AI rules and domain patterns with the objective of extracted technological features.

2.2 Market potential technique

Among the various methods present in the state of the art aimed at evaluating the technological substitution potential of two or more alternative technologies and in order to evaluate the potential for success in a market of specific products, the technique of TRIZ market potential concerns the evaluation of technological features that characterized a product [13]. These technological features regards customer needs and requirements. This approach allows to define customer needs or requirements with the aim to relocate them from a technical point of view. In addition to that, it is essential to define plans to manufacture products that meet those needs.

The market potential method offers a method to assess requirements according to two perspectives: importance (I) and satisfaction (S). Both I and S are assessed, for each requirement identified, from a customer perspective. The requirements are identified by experts in the field and the procedure of evaluation of them is subjective. In detail, the Importance parameter measures the degree of a requirement to influence the customer decision and it is based on a 0-100% scale [18]. Satisfaction measures, instead, the capability of a technology to fill or overcome customer expectations for a specific requirement [19]. It is also based on a 0-100% scale. For both Importance and Satisfaction, 0% means that the requirement has the lowest degree of importance or satisfaction, while 100% the highest degree of importance or satisfaction. The importance is used in accordance with the application and it is dependent by it. The satisfaction, instead, is evaluated for each technology.

2.3 Indicators to measure innovation

When we talk about innovation indicators, a distinction must be made between what are considered innovative input indicators and what are called innovative output indicators: input ones when we generally mean to define that category whose objective is to measure the available resources. With output indicators, instead, it is usual to define that type of parameter whose aim is to measure the results of the activity, and are particularly useful for making references with other organizations. In the case of innovations, on the other hand, output indicators measure the actual innovative performance.

The main problem, with reference to the measurement of innovative activity, is precisely to identify appropriate measures as indicators of innovative input and output, thus becoming necessary to decide the level of analysis; if one wanted to measure the innovative activity of individuals, a good indicator would be the scientific productivity of the various researchers (scientific publications), while if one wanted to measure the innovative activity of projects and organizations, it would be necessary to focus attention on companies, universities, and research centers.

3 Proposal

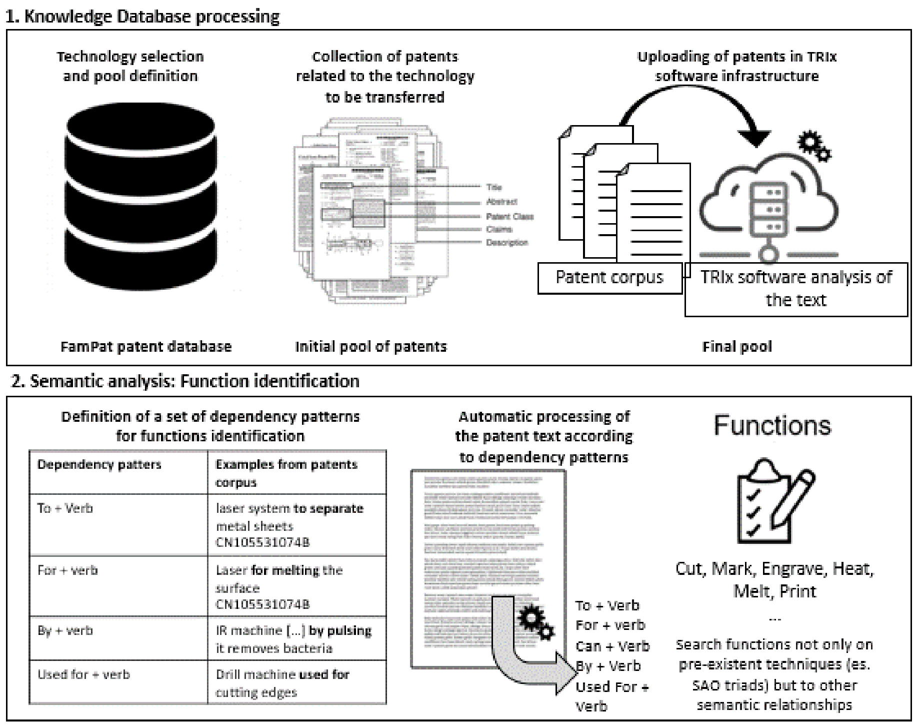
3.1 Automatic identification by semantics of technological features (function, product, requirements) of a technology

The development and implementation of the methodology aimed at the definition of requirements for technology comparison is a four step process as schematized in Figure 1. The first step consists in the definition of the patent pool, the document source on which rely to carry out the identification analysis of the parameters. Once a complete set of patent pool is compiled, a semantic parsing analysis of the text is conducted with the goal to identify functions.

With the function list identified, it is possible to define a collection of dedicated dependency patterns for product identification regarding a technology. A recent study [11] has shown that the SAO triads, which is widely used in the TRIZ community, actually covers a very partial result in terms of recall and instead requires additional, more effective language patterns. The application of dependency patterns selected for the identification of technical parameters can be implemented within an NLP tool for the automatic extraction of technical requirements.

The second step of the analysis consists in parsing the patent text with the aim to collect patterns that can be used, after a manual check, to identify functions by placing the technology in a SAO triad with the syntactic role of a subject, while verb and direct object are not yet known and will be found in the next steps of the methodology with the parsing approach. A dependency semantic parser is used for that. The analysis carried out is not only based on the SAO approach technique, but complements pre-existing techniques with new semantic forms with the aim of finding more functions. In regard to the extraction of products in a semi-automatic way, also the semantic need to be assess. In particular, by operating a semantic process of the texts identified in the previous steps. Also in this case the SAO technique is integrated by other dependency patterns.

The same technique at step 1 is used to identify the comparison factors that previously were called requirements. Also in this case, the requirement collection list is extracted considering a new set of terms used as models to be managed with natural pattern language tools. Each requirement could be defined with the couple noun plus action, where the first is a technical parameter.



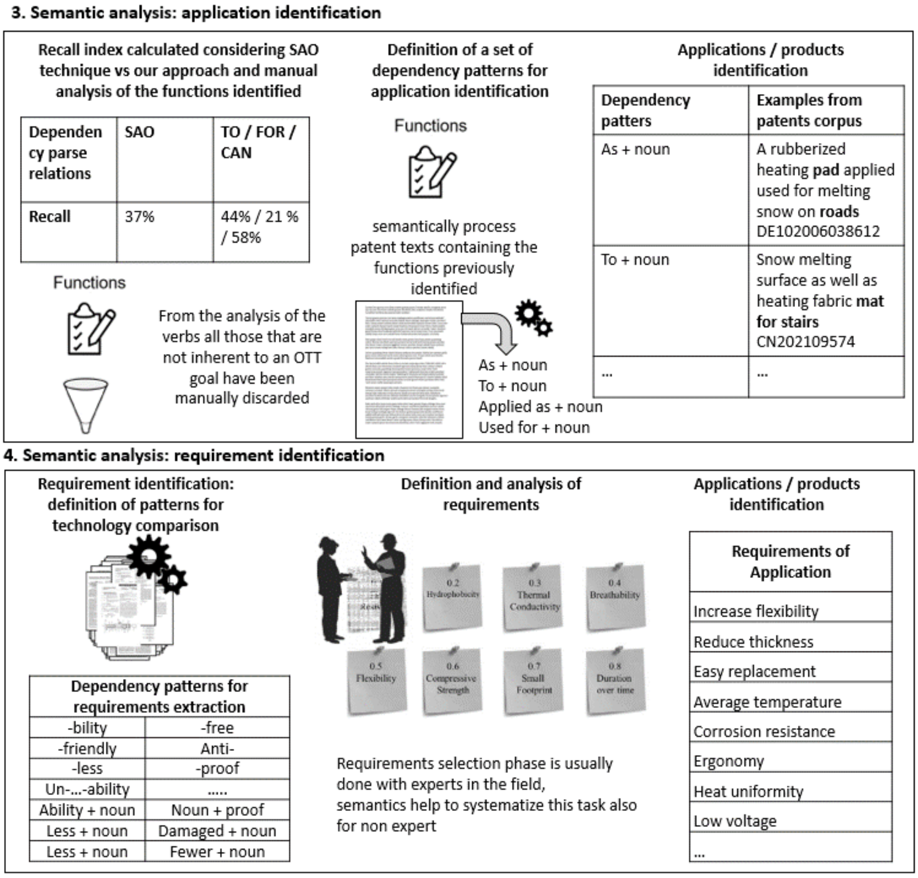


Fig. 1. Overview of the methodology for technological features identification

3.2 Evaluate the potential of the technology to be transferred: Market potential analysis

To measure the potential of the potential technological substitution, a comparison with its alternative is conducted for the identified applications. In order to do so, alternative technologies have to be identified for each domain. Semantics can also help in this regard. For the sake of brevity, the search strategies used for this task are not presented in this study. The market potential can be used as an indicator to compare the ability of different products to satisfy the identified requirements.

The limit of this approach lies in the subjectivity of the score that can be assigned to the evaluation parameters. For this reason, it is suggested to support the interviews with a patent intelligence analysis that can support the judgement with the greatest number of quantitative considerations. To select the most convenient applications for the technology transfer, the authors propose a ranking based on a comparison between the technology to be transferred (new) and one of its alternative technology (old).

Table 1 summarises all the steps that were taken to carry out the analysis, starting with the assessment of each requirement for the technology considered by applying Ulwick's market potential formula. The parameters that compose the market potential formula are divided into importance and satisfaction. Both evaluated through interviews with experts. As for the next step, regarding the comparison of the technologies under investigation, the product value (PV) is the indicator that we introduced to assess the market potential of a specific product in our case automatically extracted through semantics. Finally, a transfer potential (TP) indicator measures, by dividing the Product Value previously evaluated of the two competing technologies, the potential of technology substitution.

Table 1. Sequential steps for the evaluation of technology substitution starting from the market potential technique

Steps	Formulas
Evaluation of market potential (MP) Ulwick (2002)	$MP_i = 10 \cdot (1 + \frac{Ii}{100} + (\frac{Ii}{100} - \frac{Si}{100}))$ MPi = market potential of the requirement i for the technology considered; Ii is the importance and Si is the satisfaction of the requirement i.
Product Value (PV)	$PV_k(m,p) = \sum_{i=0}^{n} [S_i(m) * MP_i(m)] / \sum_{i=0}^{n} [S_i(p) * MP_i(p)]$ Si(m)and Si(p) are the satisfaction of two different technologies m and p in regards to the requirement i.
Transfer Potential (TP)	$TP\ (Transfer\ Potential) = \left(\frac{PV\ \ (Tech_{new})}{PV\ \ (Tech_{old})}\right)$ The transfer potential value of a certain application is the ratio between the product values (PV) of the technologies. If TP>1 the technology transferred is recommended. If TP≈1, there is no evidence to recommend a technology transferred. If TP<1, the technology transferred is not recommended.

3.3 Evaluation of the product identified according to economic parameters

The indicator adopted to position the product according to economic parameters is a function of two different dimensions: the patent cost growth trend and the economic growth trend over time.

The Patent Growth is an index that measures the evolution of patent applications (first publication year) over time. By studying the portfolio of a sector, it is possible to observe different profiles and these profiles depend on the filing strategy implemented by the applicants. Therefore, a growing portfolio may indicate that the applicants in the sector are in the phase of construction of their portfolio.

The method adopted for this analysis is the cost based method. With this method we have the knowledge of all the costs incurred to date in order to be able to evaluate any technology. We have all the patent data from databases and we are aware of all the costs incurred. These informations are available on every official website of the patent offices in every country. In addition, it is not necessarily to make any future assumptions or forecasts, as is the case with the other methods described.

The methodological steps followed for the analysis started with querying the patent database with the aim of colleting patents and subdivide the patent corpus according to the year of publication. Then we applied the cost based method for the calculation of the patent cost. This method is carried out individually for each individual patent and takes into account the sum of all the discounted costs incurred by the owner for filing, patent extensions and maintenance cost fee over the years.

Other methods adopted to evaluate the economic growth value is the Earnings Before Interest and Taxes (EBIT), a measure of a firm's profit that includes all incomes and expenses (operating and non-operating) except interest expenses and income tax expenses. EBIT is a margin that measures the company's profit deriving only from ordinary operations and its result is the difference between the revenues obtained from the sale of goods or services subject to the company's activity and the costs incurred to realize them (commercial expenses, production costs, administrative and general expenses).

3.4 Measuring the technological substitution of two competing technologies

At this stage we need to measure the feasibility and opportunity to transfer the given technology into each of the new products identified in the previous steps. To do this it is necessary to collect and organize, for each product, as much information as possible, retrieving it from the different sources identified and proceeding with an assessment of the matching between the functionality granted by the technology and the requirements of the product.

In order to assess the convenience of performing a technological substitution of an application with two alternative technologies, the authors defined a tool called technology substitution graph. The matrix, divided into four areas, allows heads of companies, start uppers, business angels and all the players active in the technology supply chain to have a guideline to guide the choice of investments in a changing environment subject to technological and economic change (Figure 2).

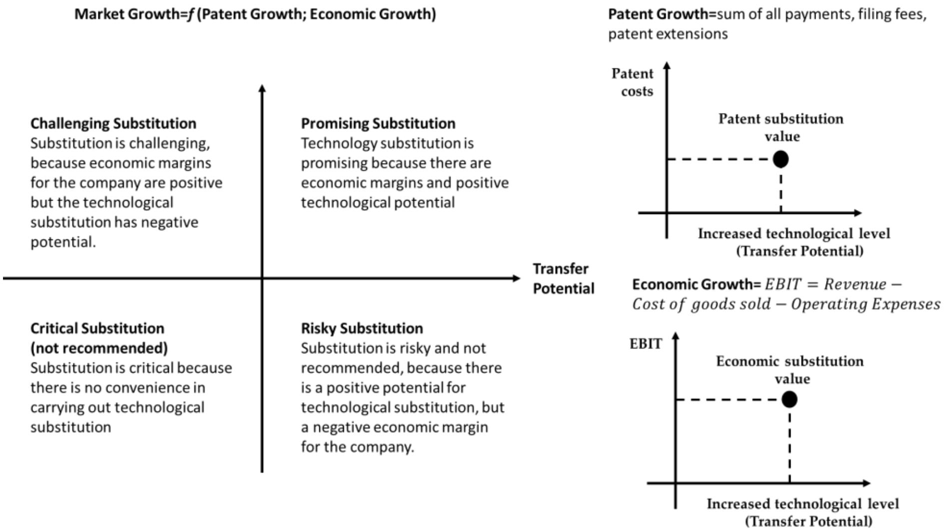
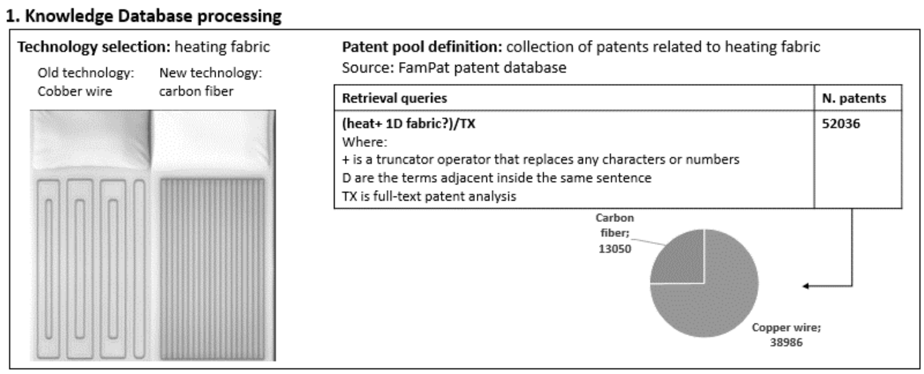


Fig. 2. Technology substitution graph components

4 Case study

The methodology was tested in a case study regarding heating fabric technology. The development and implementation of the approach is schematized in five steps, as reported in Figure 3.



2. Semantic analysis: Function identification

Processing patents to extract functions according to FOS method

Input data: Heating fabric

Dependency patters	Examples of phrases from the patent text
To + function	Carbon fiber to heat
For + function	Heating fabric for melting snow
Used to + function	Fabric used to dry surfaces
Can + function	Heating fabric can control temperature
Used for + Function	Heating fabric carbon fiber used for storing energy

Functions identified
Heat
Melt
Dry
Control
Store

3. Semantic analysis: application identification

194 different identified applications

Applications identified		
Blanket	Health waistband	Battery blanket
Heating mat	Belt	Carpet
Heating pad	Wheelchair blanket	Whidshield
Insoles	Neck protection garment	Heating asphalt
Scarf	Pillow	Emergency relief house
Mattress	Automobile seat	Door
Stir drier	Motorbike saddle	Deicing
Floor heating	Sofa	Greenhouse
Tobacco chamber	Foot warming	Cap

4. Semantic analysis: requirement identification and market potential analysis

Requirements of Heating mats	Market Potential (Carbon)	Importance %	Satisfaction % New Tech (Carbon)	Satisfaction % Old Tech (Copper)
Increase flexibility	21	90	70	50
Reduce thickness	4	0	60	40
Easy replacement	7	0	30	30
Average temperature	0	0	100	100
Corrosion resistance	0	0	100	20
Ergonomy	6	30	100	100
Heat uniformity	6	30	100	90
Low voltage	20	90	80	20
Reduce weight	0	0	100	100
Cable dimension	0	0	100	100
Temperature/heat precision	8	30	80	80
Heat dissipation	4	0	60	60
Thermal inertia	8	30	80	50
Wave emission (medical)	12	30	40	10

Transfer potential analysis

	Product Value (PV) Carbon	Product Value (PV) Copper	Transfer Potential (TP) (PV) Carbon / (PV) Copper
Heating mat	70	45,4	1,54

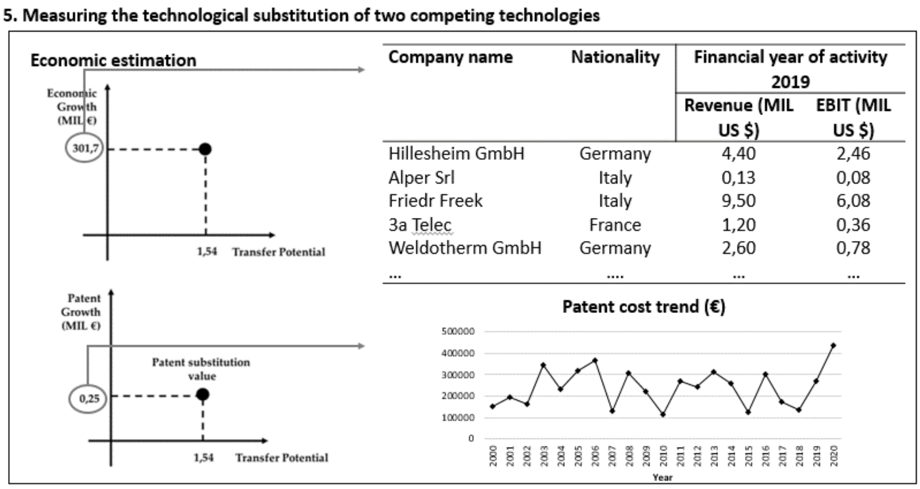


Fig. 3. Overview of the five steps taken to conduct the analysis for heating mat case study

5 Conclusions

The validation process of the proposed methodology involved several actors from industry, banking and TTOs of universities. From each of these stakeholders we collected feedback of a different nature based on the objectives of interest to them. These feedbacks were incorporated into the methodology. The collaboration with the corporate world allowed us to test the methodology in 5 different case studies: from heating fabric to energy harvesting. In the academic field, the proposed study has become an experimental service offered by the technology transfer office (TTO) of the university of Bergamo. The service is aimed at lecturers and research groups presenting project ideas at a suitable level of technological maturity or patents with the objective of facilitating outward technology transfer. The case studies dealt with textile coatings, sol-gel technology, shielding materials for buildings and innovative photocatalysts for the treatment of drinking water. The outputs obtained in these cases were aimed at the identification of collaborations and the organisation of business matchmaking events.

The discussion on market potential conducted so far mostly concerns the advantages that the technological substitution could guarantee during the use phase. The comparison could be enlarged by discussing the requirements in relation with the other phases of the life cycle. The research about an approach for defining and managing the requirements alongside the entire life cycle is planned among the future developments.

Finally, the method was tested in collaboration with banking intermediaries where the results of the analysis were included de facto in the due diligence and strategic plans of banking institutions active in technological investments.

The synergic collaboration with different actors of the territory, each with different competences, allowed us to receive many positive feedbacks from technicians and experts of the sector, who understood the potentialities offered from the point of view of technological transfer to the outside. Banking intermediaries active in the world of TT have shown difficulties in applying the methodology due to factors that are not strictly technological, such as macroeconomic and due diligence factors, which will be studied in future research. These feedbacks allow us to state that it will still take some time, at the current stage, to guarantee the results obtained and a massive application of the study in heterogeneous areas, in terms of subjects involved.

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