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TRIZ REVERSE: A SYSTEMATIC REVIEW AND COMPARISON WITH EXISTING KNOWLEDGE AND TECHNOLOGY TRANSFER TOOLS

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Abstract

The reverse version of TRIZ known as TRIZ Reverse is used in technology and knowledge transfer processes to identify appropriate industries and market segments for deploying new technology. This paper aims to make a comparison of TRIZ Reverse with other tools in technology and knowledge transfer through basic qualitative comparison criteria and a clustering model, with which all tools were contrasted, resulting in a classification according to their similarities and divergences. The output offers a rich understanding of the nature and application of TRIZ Reverse and the other instruments, taking into account the purpose, requirements and conditions of the specific transfer process.

Keywords: *TRIZ, TRIZ Reverse, Technology Transfer, Technology Transfer Tools.*

1 Introduction

Several disciplines have included the use of the TRIZ Reverse technique in the assessment of new products and their feasibility of implementation. For instance, Ngassa et al. [1] obtained relevant information related to diverse applications for a shape memory alloy developed in a French research laboratory. Glaser and Miecznik [2] evaluated a company's flagship product running market research on a cost-effectiveness basis, where the favourable results led to the identification of specific market segments for the product.

In turn, Brokmöller, et al. [3] implemented TRIZ Reverse to evaluate the feasibility of manufacturing components using tailored forming technologies. They found the specific contradiction-duet to discover a variety of uses for tailored forms as well as which features of the regularly used components had to be modified. Furthermore, Kloock-Schreiber et al. [4] visualized the areas in which Product Service Systems could be utilized, managing to identify the Inventive Principles (IP) contained in the technology and discovering the contradictions it solves.

It would be necessary to have a larger variety of tools besides TRIZ Reverse to replace it as the operator of the transfer if necessary, or to fill the gaps it may have in achieving a successful Technology Transfer Process (TTP). Therefore, it is imperative to find other tools that enable the dissemination of technology and compare them with TRIZ, in order to discover the existing alternatives and obtain accurate information about their specific attributes. These necessities became the source of research for this study.

2 Literature Review

2.1 Searching Approach and Methodology

A qualitative analysis was taken as reference, based on the descriptive-comparative method. The descriptive method aims to provide information regarding the characteristics of an entity or phenomenon. This description can be either quantitative or qualitative [5].

The research process was carried out in the following stages:

1) Information collection: scientific documents were collected from both electronic and physical resources. The digital resources were extracted from the academic information bases Emerald, Jstor, Oxford journals, Proquest, Researchgate, Sage books, Sage journals, Sage premier, Science direct, Scielo, Springer palgrave books, Springer link journals, Taylor and Francis journals, Wiley online library and from websites specialized in the subject under study, using keywords and key phrases such as Knowledge Transfer, Technology Transfer (TT), Technology Transfer Methods, Technology Transfer Tools, Technology Transfer Instruments, among others.
2) Selection of the documentary material, obtained through the reading of abstracts and conclusions to define their relevance to fulfil the research purpose.
3) Literature analysis and design of the conceptual framework for the study.
4) Construction of the research approach and methodology for information analysis.
5) Definition of variables and criteria, supported in the general characteristics found for each TT tool in the literature review.
6) Analysis of the information using a systematic comparison methodology by means of a contrast matrix, taking the variables and criteria in point 5) as the elements to be compared.
7) An additional cluster analysis using statistical software was performed to have another practical-comparative perspective with the aim of finding a classification of tools according to their features.

According to the scientific literature included in the analysis, the overlapping of terms such as method, instrument, tool, approach and channel was noticeable. To carry out the comparison exercise, 'Tools' were considered as complex elements that operationalize the Technology Transfer (TT) by their execution, i. e. these elements that trigger the process linking technology resources to business objectives [6].

2.2 Technology Transfer Tools: Overview

The literature review revealed elements with the characteristics of the definition of 'tool' mentioned above. From a chronological perspective the elements selected to compare with the corresponding author are shown in Figure 1.

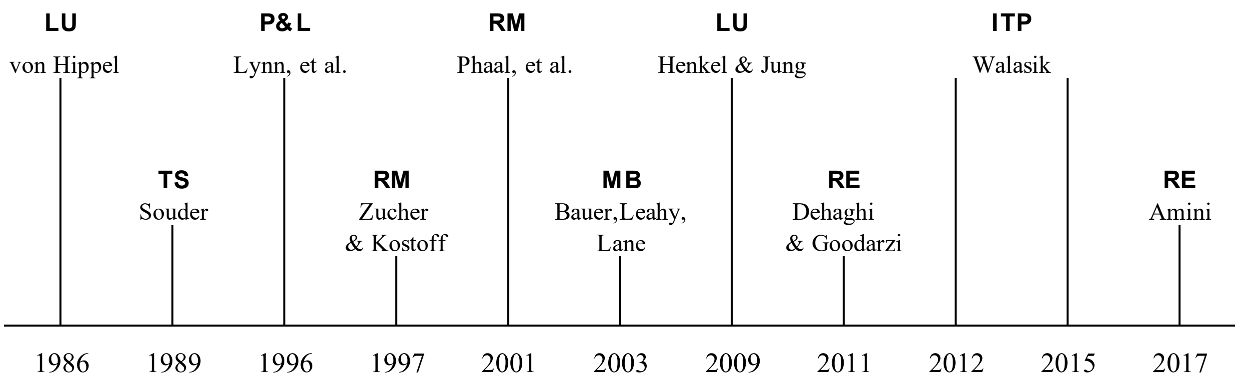

Fig. 1. Tools included in the study – Chronological perspective

1) *Lead User* (LU) is built on the assumption that there is a defined industry or sector where related lead users can be identified. They are invited to co-create product concepts based on their needs [7]. LU embraces four major activities: identifying the trend, identifying lead users, analysing lead user data and projecting lead user data into the general market of interest [8]. An alternative version of the LU is the Technology-Push User Concept (T-PLUC) outlined by Henkel and Jung [7], in which the difference is that T-PLUC starts with a given technology instead of a market trend.
2) *Total System* (TS) seeks to increase technology-push success rates by removing the main transfer barriers through the active involvement of the inventor along with the technical and commercial team. The inclusion of the technology creator promotes interdisciplinary interaction and turns unfamiliar technology into familiar technology. In doing so, basic and complex usages as well as different potential markets can be identified. It recognizes that some combination with pull strategies strengthens the method, e.g., prototype tests with consumers or free demonstrations [9].
3) *Probe & Learn Method* (P&L) is based on the idea that there is a product embodying a new technology and that there is one or more markets to serve with its application. This is a technique in which the inventor tests early versions of the product in its potential markets with a cyclical learning and testing process consisting of three general stages: probing, learning and iteration. In each stage, the technology is shaped and improved according to the acquired information [10].
4) *Roadmaps* (RM) are utilized in TTP for handling a large amount of information required to find a path for implementing innovation. Being a Graphical Modelling System (GMS), RM graphically portrays relationships between R&D and potential applications. With the use of this tool, researchers can see the big picture of the context and find new functions and uses, having a complete mapping of resources and information flow. Since this relationship can be made through several pathways, a roadmap also functions as a tool for decision-making to find the best alternative [6], [11].
5) *Market Brokering* (MB) has been widely explored by federal laboratories and other research and promotion centres of innovation. It begins with the existence of advanced technology or advanced stage prototype that seeks an application in the market under the assumption that this novelty will add value to existing product lines in the marketplace [12]. Even though many technological developments meet specific needs with new features and functions, the manufacturers often do not have detailed market information (e.g., market size, market segmentation and penetration, etc.) or do not know how to obtain it [13]. This tool removes these marketing barriers by capturing the technology target through a flow of key information that enables a well-informed licensing decision [14].
6) *Reverse Engineering* (RE) has been considered a useful mechanism in the TTP mainly in developing countries to access the technical knowledge comprised in machines or any advanced technology in its final development stage. The technical information is extracted by breaking down the product into its parts, for example, if the information about its planning and design is not available. With this knowledge, it will be possible to use the technology, maintain it, copy it or build a new one with similar characteristics and new specifications [15], [16].
7) *Information Technology Platforms* (ITP) serves as a tool for marketing activities execution at research organizations that seek to strengthen relations between the R&D sector and companies, allowing for optimal implementation of research results [17]. The functional activities supported by the technology transfer platforms are: disseminating scientific research results, horizontal activities (promotion, promotional products preparation supervision, product distribution), marketing activities, support in the process of International TT, brokering, building consortia, carrying out related projects, managing electronic tools supporting cooperation and evaluate innovative products [18].

3 TRIZ Reverse

3.1 Philosophy and Approach

TRIZ Reverse is based on the idea "solution seeks problem". Therefore, new potential problem areas are to be identified to deploy the innovation, starting from a complete understanding of the technical solution. Current research outputs show that this is possible and that the principles that allow the exploitation can be extracted from the use and/or sale of patents [19]. In 2020, the exploitation of patents in commercial terms was 36% in the European Union and only 10% of these were deemed insufficient for commercialization [20]. The figures suggest the great opportunity to convert knowledge into marketable technology that contributes to the progress and economic growth.

The scientific foundation of TRIZ Reverse is rooted in the concept 'reverse inventing', which refers to the process through which the strengths of a company or research agent are initially tracked and found and transferred to an abstract form. Finally, the market is analysed by seeking the possible beneficiaries of the offer [2]. TRIZ Reverse requires a reduced solution that reveals the IPs and contradictions that relate to the technology; however, hundreds of concepts can be found [1], [4]. To solve this problem Mann [21] created a search word catalogue for patent database analysis. There are several suggestions for the application of TRIZ Reverse. Depending on the aim of the investigation, the algorithms comprise 4 to 8 steps to find suitable new areas of application [2], [22].

3.2 Six-step Procedure

The procedure for finding potential users of the intellectual property contained in the patents is implicit in the study carried out by Glaser and Miecznik [2], in which TRIZ Reverse was employed to find market opportunities for the core capabilities of a specific company. The process stages followed by the authors were:

1) Analysis and target setting.
2) Back-tracing of product strengths to IP.
3) Translation/abstraction of IPs into typical search phrases for patent databases.
4) Database analysis of selected search phrases.
5) Analysis of search results matching market opportunities.
6) Business planning and action deployment.

The scholars stated that it is essential to establish the core competences of the company, commonly reflected in successful products or the results of competitive analyses. With the aid of this clear information, it is possible to identify the research targets that will enable the technology to become a significant player in a previously unattended market. In the next stage, a back-tracing of technology core-features to IPs takes place. The author proposes the use of 'product DNA theory' to find the key elements that lead an IP to be found; nevertheless, other abstraction methods can be employed.

Once found, IPs can be translated into common search phrases to perform a database search (intellectual property databases). A number between fifty and five hundred hits per query is considered optimal, taking into account up to the third hierarchical level of the international patent classification code (IPC) for each case. The set of patents found constitutes the field of exploration to find market opportunities. After refinement utilizing conventional strategic business management tools, the business plan and strategy are developed and implemented [2].

4 Comparison Tools

4.1 Criteria-based Evaluation

Conceptual macro-areas or dimensions were defined to characterize the tools. Some of them were established by Weijo [23] as the influencing factors for choosing a TT strategy. However, customized dimensions inherent to the object of research were constructed by extracting, analysing and grouping key information from the literature. These are the dimensions considered for the comparison:

- *Dimension 1 – Purpose:* refers to the core aim of the tool. It answers the questions: What is the purpose of the tool? What need does the tool fulfil?
- *Dimension 2 – Market approach character:* corresponds to the market-approach style and answers the question: Does the tool actively seek out market opportunities? Therefore, the possible values are, *passive* if the tool makes information accessible to individuals looking for technological solutions, or *active* if it promotes technology in the market [23].
- *Dimension 3 – Stage of research and development:* refers to the development point needed to initiate the TT, which answers the question: At which stages of development is it possible to use the tool? The possible values are *early* if premature stages of technology before prototyping are necessary, *middle* if a prototype is needed, *late* if a consolidated technology is required as input and, *any* if the tool does not require a specific stage of development.
- *Dimension 4 – Structure of the distribution channel:* related to the driver with which the tool operates and answers the question: Is the tool market-driven or technology-driven? Therefore, the values are *pull* if it works from an identified need in the marketplace toward the necessary technology to solve it, *push* if it works from an innovative technology toward the identification of a need and marketplace, or *mixed* if it has pull and push mixed characteristics
- *Dimension 5 – Process shape:* deals with the process type identified in the tool implementation and answers the question: Does the application of the tool fulfil its purpose with a single-use or are more cycles required? In this case, the values are *linear* if only one usage is required to achieve the goal, *cyclic* if more than one use is needed, and *mixed* if the process has both linear and cyclic characteristics.
- *Dimension 6 – Market focus:* related to the market-targeting goal and answers the question: Does the tool focus on a specific market? For this dimension, the values are: *focused* if the tool is directed towards a specific market, or *diverse* if multiple markets are the target.
- *Dimension 7 – Agents' interaction:* refers to the participation of own agents or third parties in the application and answers the question: Does the tool require (or makes necessary) the intervention of several actors in its implementation? The possible values are, *interactive* if it includes a variety of agents, or *unilateral* if it includes just a few or no agents.
- *Dimension 8 – Focus on communication:* related to the existence of formal ways and channels of communication, which answers the questions: Does the tool require (or makes necessary) two-way information transfer? Does it promote a formal means of making communication constant? Therefore, the values are: *formal* if the tool requires or promotes formal ways and communication channels, *informal* if formal ways and communication channels are absent and, *mixed* if formal and informal ways of communication are present.
- *Dimension 9 – Knowledge requirements:* refers to the technical skills required for the tool operation and answers the question: Is specialized knowledge required to apply the tool? The values are *specific knowledge* if specialized skills are required in the performing and *intuitive* if just common or intrinsic knowledge is necessary to use the tool.
- *Dimension 10 – Optimization of resources orientation:* corresponds to how the resource-use is addressed and answers the questions: Does the tool take into account the appropriate

use of resources? Is it based on cost reduction? Therefore, the values are *resources optimizer* if the tool is efficiency-oriented and *resource dispenser* if not.

For an accurate visualization of results, a comparison matrix was constructed. The columns represent the tools and the rows represent the dimensions. Their intersection takes a particular value according to the definitions of each dimension. The similarities with TRIZ Reverse are highlighted in green and the differences remain unmarked (Figure 2). For the dimension 'purpose', although there are specificities according to each tool, since all of them seek industries, market segments and users for technologies, a total complete similarity is assumed.

No.	Tool / Dimension	TRIZ-R	LU	TS	P&L	RM	MB	RE	ITP
1	Purpose								
2	Market approach character	Active	Active	Active	Active	Active	Active	Passive	Passive
3	Stage of research and development	Late	Any	Middle	Middle	Any	Middle	Late	Any
4	Structure of the distribution channel	Push	Pull	Mixed	Push	Mixed	Mixed	Push	Mixed
5	Process shape	Mixed	Linear	Cyclic	Cyclic	Linear	Cyclic	Linear	Cyclic
6	Market focus	Diverse	Focused	Diverse	Diverse	Diverse	Focused	Diverse	Diverse
7	Agents interaction	Unilateral	Interactive	Interactive	Interactive	Interactive	Interactive	Interactive	Interactive
8	Focus on communication	Informal	Formal	Formal	Informal	Mixed	Formal	Formal	Formal
9	Knowledge requirements	Specific knowledge	Intuitive	Intuitive	Specific knowledge	Specific knowledge	Specific knowledge	Specific knowledge	Intuitive
10	Optimization of resources orientation	Resources optimizer	Resources optimizer	Resources optimizer	Resource dispenser	Resources optimizer	Resources optimizer	Resource dispenser	Resources optimizer

Fig. 2. Comparison Matrix (Contrast)

By performing a comparative-absolute analysis1 (solid colour) is obtained that the most similar tool to TRIZ Reverse is P&L with 6/10 coincidences, while the most different are ITP and LU with only 3/10 equal values each. The absolute qualitative comparison scenario concerning TRIZ Reverse from greatest to least similarity is as follows: P&L (6/10 – 60%) → RM and RE (5/10 – 50%) → MB and TS (4/10 – 40%) → ITP and LU (3/10 – 30%). However, in the

[1] The Comparative-absolute analysis refers to strict compliance with the value of the dimension, i.e., the value of tool x is considered to be absolute-equal to the value of TRIZ Reverse because they are exactly the same. To claim that a tool is equal in the 'market approach character' dimension to TRIZ Reverse it is necessary that both have the 'active' value. This rule also applies in the dimensional analysis.

comparative-relative analysis2 (gradient colour) the scenario changes; RM is the most similar tool with 9/10 coincidences and LU is the one with the greatest difference with only 5/10 similarities. The relative qualitative comparison scenario with TRIZ Reverse from greatest to least similarity is as follows: RM (9/10 – 90%) → P&L (7/10 – 70%) → MB, ITP, TS and RE (6/10 – 60%) → LU (5/10 – 50%).

Performing the same contrasting exercise taking dimensions as the subjects to contrast, the comparative-absolute analysis shows that besides 'purpose', 'market approach character', 'market focus' and 'optimization of resources-orientation' are the most homogeneous among the cases, since the value assumed by TRIZ Reverse in these dimensions is shared by 5/7 tools. 'Process shape' and 'agents interaction' are totally heterogeneous with TRIZ Reverse, since none of the cases share the same value.

The absolute comparative analysis by dimensions from greatest to least similarity is: 'market approach character', 'market focus' and 'optimization of resources-orientation' (5/7 cases – 71,4%) → 'knowledge requirements' (4/7 cases – 57,1%) → 'structure of the distribution channel' (2/7 cases – 28,6%) → 'stage of research and development' and 'focus on communication' (1/7 cases – 14,3%) → 'process shape' and 'agents interaction' (zero cases).

On the other hand, the dimensional comparative-relative analysis shows a different performance; 'process shape' is the fully homogeneous dimension with 7/7 coincidences, while 'agents interaction' continues as the only dimension with zero-similarity; the result of the relative dimensional analysis, from more to less similarity, is: 'process shape' (7/7 – 100%) → 'structure of the distribution channel' (6/7 – 85,7%) → 'market approach character', 'market focus' and 'optimization of resources-orientation' (5/7 – 71.4%) → 'stage of research and development' and 'knowledge requirements' (4/7 – 57,1%) → 'focus on communication' (2/7 – 28,6%) → 'agents interaction' (zero cases).

4.2 Statistical-based Evaluation

As previously mentioned, a clustering analysis was conducted using SPSS. Although the number of cases and attributes is small, the quality of the model is 'fair' obtaining two defined clusters. This means that the outcome is representative and suitable to continue with the analysis. According to the internal analysis carried out by SPSS, the first cluster contains three cases, TRIZ Reverse, P&L as well as RE and the second cluster contains the remaining five cases, MB, ITP, RM, LU and TS. SPSS takes as a basis the variable or 'predictor' that differentiates the most among all cases to perform the comparison. For this specific study, SPSS ranked 'structure of the distribution channel' as the most important variable to classify each case. Figure 3 shows the order of how the other dimensions were included as criteria for separation, i.e., the ranking of similarity related to dimensions according to the clustering-model, where 'structure of the distribution channel' is most heterogeneous within the cases.

According to the output data the following two clusters can be assumed:

- The first cluster contains the tools TRIZ Reverse, P&L and RE. Based on their characteristics, they can be summarized as 'diverse-market and push-oriented advanced tools'. Their

[2] The Comparative-relative analysis takes into account the fact that for some dimensions the observed case can take several values. In this case, the similarity is assumed if a tool reflects all the values and TRIZ Reverse only one of them or vice versa. For example, for the 'stage of research and development' dimension, a case is considered similar to TRIZ Reverse if it takes the value 'late' or 'any', as it includes the value 'late' shown by TRIZ Reverse. This rule also applies in the analysis of dimensions.

use can be considered as effective if push market orientation and focus on various market opportunities in various segments, industries and users are required. However, it must be taken into account that specialized knowledge is essential for their successful implementation. These tools are not appropriate for promoting technology in the early stages of development and their specific use should be reviewed if a cost reduction objective is aimed.

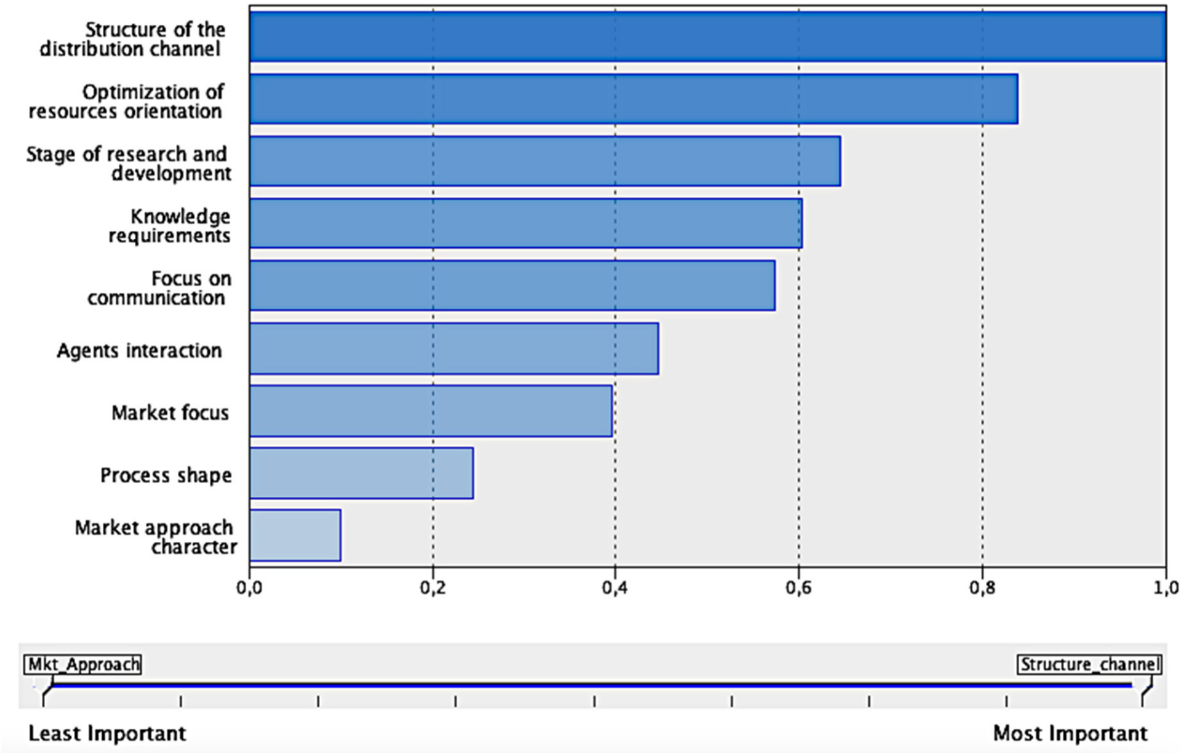

Fig. 3. Predictor importance ranking for clustering analysis

- The second cluster contains the remaining tools MB, ITP, RM, LU and TS. They can be summarized as 'collaborative-active push and pull driven tools'. The use of these tools is assumed to be effective in an active, push-and-pull oriented TT with a complete orientation towards optimizing costs, including permanent interaction between agents through formal communication channels, which is the aim at any stage of technology development.

5 Conclusions

Both the systematic analysis carried out through dimensional comparison and the clustering carried out in SPSS show the existence of similar and dissimilar tools concerning TRIZ Reverse, but neither can be found to have identical characteristics. These two analyses show that the starting point in their process determines the result in terms of differences and similarities:

1) The systematic-comparison analysis based on the 1-to-1 contrast of each dimension between TRIZ Reverse and the other TT tools, results in a similarity ranking that despite having a defined frame of reference has no analysis context beyond simple contrast. The results obtained with this method are also useful to establish what elements differentiate the subject-reference (TRIZ Reverse) from other tools and how this relationship of semblance or distinction is expressed.
2) With the cluster-based analysis it is possible to obtain dissimilar groups. Although this method is also based on dimensional-contrast, the comparison is carried out among all the TT tools, taking as a guiding principle the most heterogeneous dimension to establish the

relationship between them. Since each dimension has specific importance in the differentiation and that all cases are compared between them iteratively, the outcome scenario probably minimizes the bias of the systematic comparison obtained from the contrast matrix.

Considering the above information, it is feasible to infer that although the differences between the findings in the results from the two types of analysis are evident, it is not possible to affirm that they are mutually exclusive, since their method of differentiation is distinctive. Hence, both provide valuable information regarding the characteristics and use of TRIZ Reverse and the other TT tools. This data can serve as key information for decision-making regarding the use of one or another TT tool according to the objective and specific conditions in a particular TTP.

Through the methodology used and the instruments employed to carry out the analysis, it was possible to make such contrast, reaching relevant findings from a theoretical and practical point of view. In the theoretical field, the methodological structure implemented can serve as a conceptual reference framework for the characterization and assessment for a TT tool, since a relevant number of dimensions were defined to collect relevant data from all the cases included in the study, which can be used in other research activities.

When it comes to the practical relevance, the results obtained suggest a selective implementation of TRIZ Reverse or one of the other tools according to the specific conditions and requirements in a TTP contained in the dimensions designed as part of this study, for example, the state of development of the technology to be transferred, the use of resources in the TTP, required knowledge to perform the process, among other considerations.

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