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THEORY OF INVENTIVE PROBLEM SOLVING (TRIZ) AND ITS POTENTIAL IN COMMERCIALIZATION PROCESSES

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Purpose: The purpose of the article is to match TRIZ and TRIZ - business tools with the stages of technology development and elements of the commercialization process.
Design/methodology/approach: This paper is conceptual and theoretical. The study reviews key existing literature in areas of TRIZ and TRIZ business as well as commercialization. This was the basis for indicating the role of TRIZ in the innovation process.
Findings: A major barrier to commercialization is the increase in costs at successive stages that bring an idea closer to the marketable product stage. TRIZ can be used to reduce the cost of solving business problems – by assuming that a solution idea can be developed independently of the basic research and also allows to get an idea with high functionality and expect that it will be better received by the end customer.
Practical implications: TRIZ improves idea generation or product and process improvement. Modifications of TRIZ – Business provide tools to understand and solve organizational problems.
Originality/value: The originality of the paper is to relate selected tools of the methods to technology readiness levels and problems of the commercialization process with the use of the TRIZ technique for business activities.
Keywords: TRIZ; innovation; commercialization.
Category of the paper: conceptual paper.

1. Introduction

TRIZ, as one of the recognized engineering methods, has been successfully used in various industries since the middle of the last century. Its practical applications were greatly increased with the collapse of the Soviet system and the process of "exporting" its scientists and technical thought beyond the collapsing Eastern Bloc. Since then, the popularity of the method has grown rapidly, finding its application mainly in innovative industrial companies located both in the Far East (mainly in South Korea with many implementations by business leaders such as

Samsung) and in the United States (where there are many examples of successful implementation in companies, e.g. Boeing).

The popularity of the TRIZ methodology has grown rapidly due to its high effectiveness in rationalizing costs of many activities (mainly of a technical nature), which translates into not only technical or organizational success, but also (and perhaps above all) economic success. Typical engineering applications do not exhaust the entire potential of using the TRIZ methodology in a company. In recent years, there have been more or less successful attempts to use this solution in other business areas, concerning both the company as a whole, as well as its functional departments.

Taking into account the above-mentioned possible applications, as well as considering the potential and significant possibilities of using the TRIZ technique for business activities, the main objective of the current study will be to present the TRIZ methodology for increasing the effectiveness of technology commercialization processes in enterprises and research and development institutes.

2. TRIZ – evolution of the concept

The origins of modern Theory of Inventive Problem Solving (TRIZ) date back to the 1940s. In 1946, Henry Altszuller, employed as a clerk in a patent office, began research on establishing general principles of invention, at first in relation to his own ideas, to devote himself after a few more years solely to discovering the path leading to new inventions (Altszuler, 1972). Altszuller had been interested in technology and invention since childhood. In the course of his technical activities, he came to the conclusion that a method of organizing creative proceedings was lacking, more specifically, the part concerning the solution of technical problems (which was later formulated in the form of, among other things, an algorithm). In order to search for common points in existing solutions, he analyzed several thousand patents to which he had access (Cardenal, 2018).

The question that may arise for the reader who has not yet encountered TRIZ may be as follows: is a system developed in the USSR in the last century still worth something in the world of 21st century capitalism? The answer to this question, based on cases of companies that use TRIZ, such as Samsung or Boeing, is yes. TRIZ does not provide an answer to all problems related to the development of new products, it focuses on the part of creative activity that concerns the manufacturer - the consumer has a supporting role, if an engineer using the method includes him in the so-called super system, i.e. the product environment. The method does not provide for the involvement of end users or marketing specialists at the early stages of the production process, in accordance with the popular concept of design thinking, as it is directed at solving a technical problem without considering the issue of its packaging.

The historical setting of the method was important for the fate of the author - in the Stalinist period, when politics mixed with science Altszuller, who allowed himself to criticize the system supporting invention in the USSR was punished with a stay in the gulag and then, after leaving it, with a ban on work. Seeing no other option, he decided to write science fiction books. A TRIZ-like way of thinking manifested itself by categorizing themes from available literature and applying them to his own work.

The 1950s was a period of formulating a key concepts for the theory: technical contradiction, the ideal final solution, and the precursor of a tool today known as the so-called 9-window system (analysis of a problem in reference to the environment and time) (Karedal, 2018). The idea of the creator was to create an algorithm (i.e. a sequence of repetitive actions) that generates new solutions, eliminating the chaotic search for new solutions and counting on the brilliance of the discoverer. Instead, he proposed rules to guide the potential inventor toward the right solution. The method has been updated several times in subsequent versions.

Until the 1960s, Altszuler's discoveries received little attention from Soviet inventors; a 1959 publication in a journal devoted to problems of invention was a breakthrough (Altszuler, 1972). Growing popularity resulted in a number of workshops held at industrial plants, resulting in the development of numerous patents by participants.

Alshuler presented his method in subsequent publications, lectures, and training sessions, creating a school of his students who further popularized it in the USSR and, after its collapse in 1991, within the TRIZ association.

The most recognizable element of TRIZ, the Technical Contradiction Resolution Matrix currently consists of a list of 39 parameters that we would like to improve in a given facility and a list of parameters that will deteriorate as a result of applying a given technical solution to improve the system.

In the 1980s, the catalog of TRIZ tools was expanded to include, among others (Ikovenko et al., 2017):

- functional modelling (representation of the functions of a technical system),
- trimming, or analyzing functionality in relation to cost in order to optimize,
- cause-and-effect chain of defects (known as CECA or RCA),
- feature transfer (from other systems).

3. The potential use of TRIZ method in business

Given the nature and volume of the study, as well as a wide range of potential translation of the TRIZ methodology into the language of business, the authors do not attempt at present to take a comprehensive look at the possible implementation of TRIZ tools in business. Some areas of implementation seem obvious, they are closely related to improvements made, for example, in the production processes of the company (which applies to manufacturing companies), where some obvious relationships in the process approach and TRIZ methodology can be seen. Such a translation of the concept seems to be closest to the original approach developed by Altszuller and his successors, due to the close relationship with knowledge of an engineering nature.

However, this does not reflect the whole potential implementation of the concept in business, where for years there have been attempts to develop methods and tools based on the original TRIZ philosophy and their use in other areas of business. For some time, original studies have been appearing that attempt to develop a new use of TRIZ methodology in other areas of business. This indicates the potential of the method and its attractiveness for alternative applications.

One such example is a study by Mueller (2005), where an attempt was made to combine the concept of understanding resources in terms of TRIZ with resources understood from a resourced-based view and present the concept of Management-TRIZ. Three distinct levels of resources were distinguished - elementary, specific and concrete, and then the resources at each of these levels were analyzed in detail.

Another approach was presented by Boratyńska-Sala (2014), where potential areas of application of the TRIZ methodology were indicated in, among others:

- Marketing – where the engineering principle of fragmentation can be used to build segmentation strategies.
- Human resource management – for example, in ways to mobilize top-level management or generate new management ideas.

On the other hand, the use of the potential of the TRIZ methodology was looked at more broadly by Livotov (2008), indicating the potential of using this methodology for thinking at the level of the company's top management. The components of the TRIZ methodology for use at this level for business and management purposes are:

- identification and theoretical exaggeration of conflicts,
- a positive attitude towards complexity,
- consideration of patterns of evolution,
- anticipatory evaluation of risks,
- utilization and expansion of resources and knowledge.

There are many additional potential applications of the TRIZ methodology in business, and one of the most promising areas, which is the primary one analyzed in this study, is the commercialization of new technologies.

4. Commercialization processes – the main problem areas

We can understand commercialization in relation to the activities of scientific entities in two ways. One of them is included in the definition of innovation activities as defined in the OECD Oslo manual (2018) according to which they are: "all developmental, financial and commercial activities undertaken by a company with the intention of developing an innovation for it". This very broad definition allows to classify the entire activity of the enterprise as innovative activity, as long as this is the manager's intention. According to the definition of the PWN dictionary of Polish language, commercialization is:

- "making something commercial"
- "the first stage of privatization of state enterprises (...)".

Point 1 of the PWN definition refers to a wider range of phenomena than the OECD; in the case of scientific entities, it is the process of using assets to achieve profit by the entity. Such assets, apart from know-how or patents, which meet the OECD definition of innovative activities, may be research equipment (making it available for a fee) or the surface of real estate belonging to the entity. This type of activity is of a commercial nature, although in the case of research apparatus, due to its nature, entrepreneurs will belong to industrial units operating in the most modern areas and often undertaking the development of innovative products. Commercialization as the use of scientific infrastructure for the benefit of entrepreneurs is a process that, in order to achieve the expected results, requires taking into account the needs of entrepreneurs at the stage of its purchase and then creating a system within the organization which allows the use of devices in accordance with the needs of the entrepreneur. It is necessary to establish the rules of cooperation, to formulate an offer, to make available the personal resources of the organization and its know-how, to rent offices and industrial space, to meet additional needs of the entrepreneur or even to create a whole system of related additional services (e.g. financial, accounting, leisure and recreation services such as in the Alderley Park in Manchester, UK). Another way to commercialize is to provide unique and science-based manufacturing services, often to conduct scientific research.

Publications on commercialization rely, most often unknowingly, on one of the above definitions. For example, Gwarda-Gruszczyńska (2013) points to 3 general stages of commercialization of new technologies: concept evaluation, development stage and marketization stage, which indicates the understanding of commercialization as a stage of activities that create innovations. In addition, the distinguished stages of model fit the so-called push strategy (i.e. searching for a buyer for the developed technology), however, in the case of the pull strategy (i.e. searching for a solution to the problem coming from the business) it needs to be modified. The commercialization process begins with the entrepreneur's notification of an invention problem to scientists, to which they try to respond by formulating an idea for a solution to be tested in the implementation of the research agenda. In such a process, commercialization deals with the scientist's know-how, while the entrepreneur provides a problem embedded in a market in which they operate and are familiar with. The evaluation of the concept is done jointly by the entrepreneur and the researchers, but is limited due to the unknown final shape of the technology. Only if the research results indicate the usefulness of the idea will another in-depth analysis be performed. In the remainder of this article, we will use the term commercialization in the sense of activities that serve innovation (the aforementioned OECD definition). Indication of the first stage, which is the beginning of the commercialization process, is conventional. If one undertakes research on the basic manifestations of a phenomenon, expecting that the object may have some as yet unknown properties that will be economically useful (e.g., based on past experience with research on objects of a similar class), then leaving basic research out of the process will be a moot point. An illustration of the above situation may be the currently undertaken basic research on nanomaterials such as graphene. Initially diagnosed potentially useful properties are verified, enriching the knowledge, based on the assumption that, similarly as in the case of e.g. aluminum, after an ultimately long period of research the know-how will be obtained which can more than compensate for the resources devoted to basic research.

With respect to the above, we can distinguish a number of specific problem areas in the commercialization process:

- generation of new ideas, decision on the agenda of basic research, selection of their results for further development,
- IP protection issues, NDAs, patent applications, IP protection strategies and their limitations,
- financing the various stages of the commercialization process,
- seeking out business partners interested in the idea (known as a push strategy) or collaborating on the entrepreneur's idea (known as a pull strategy),
- creation of separate business entities for the development of an idea (start-up), or separate enterprises of a purely productive nature, as well as branches/outlets in places other than the headquarters (other provinces, regions of the world),
- the role of publications in disseminating knowledge about the innovative potential of scientific entities,
- the divergence in priorities between the worlds of science and business,
- cooperation between different entities and its effectiveness (consortia, clusters, networks),
- determinants of implementation success,
- the role of the innovation support environment,
- aspects of cultural and interpersonal problems within the commercialization process (the role of the leader, the team, optimal conditions for cooperation),
- streamlining and breakthrough innovations,

- building organizations that conduct production and research simultaneously,
- culture and working conditions in the organization that foster innovation,
- disruptive innovation as a way to change the equilibrium in a given market,
- innovation as a way to improve a company's image and its value to the customer.

We could imagine the process of commercialization of intellectual property (IP) as a way of transforming an idea (concept) in successive stages into a finished product that finds buyers in the market and achieves success. The subsequent stages of the process generate specific problems, on the solution of which further development depends. The quality of an idea and its potential usefulness do not determine its success. Without solving a number of diverse (technical, legal, organizational, financial) problems, commercialization will fail.

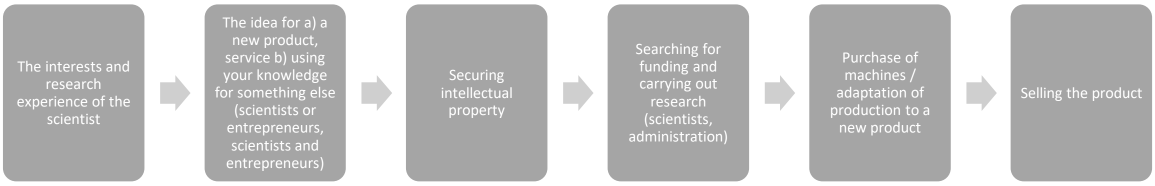

Figure 1. Commercialization process in a research unit.

Source: own study based on previous research.

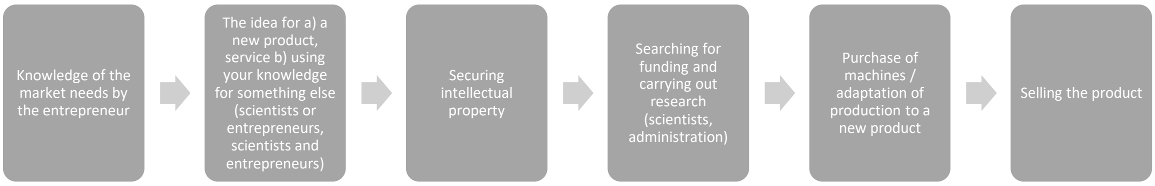

Figure 2. The commercialization process in an enterprise.

Source: own study based on previous research.

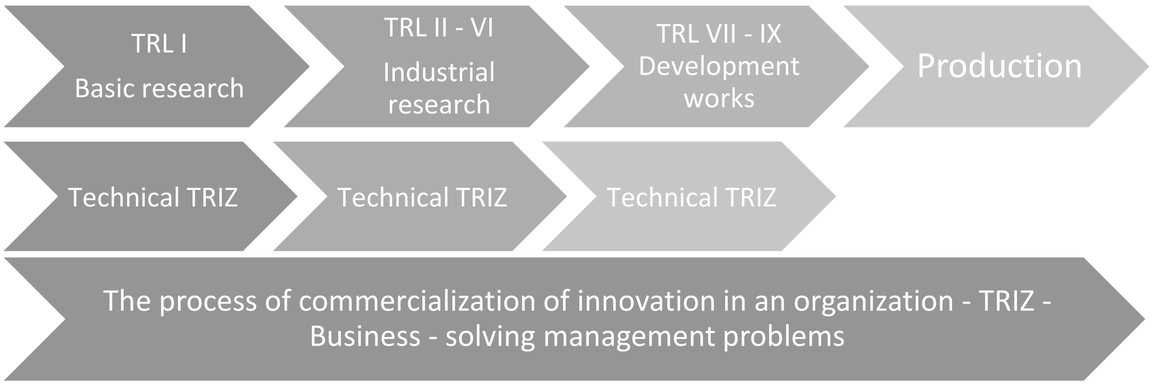

Figure 3. The role of TRIZ in the innovation process.

Source: own study based on previous research.

A commonly used approach to represent the stages of innovation development is the Technology Readiness Level (TRL) scale developed by NASA. Technology development starts at TRL1, i.e. basic research, and ends at level 9, i.e. product ready for sale.

TRIZ can be used to resolve technical contradictions that emerge at subsequent stages (TRL) of technology development. In the case of level two, it can be used to formulate an idea for a new technology, and in the period after the product appears on the market, to improve it. The production process itself, if it requires it, can be optimized (the so-called trimming).

Boeing can be used as an illustration of how to use TRIZ at different TRL levels (according to the company website) (TRL level in parentheses):

- Design Improvements - finding the right power to meet the fuel discharge rate requirements for the KC-767 tanker - (Industrial Research, II - IV TRL).
- Creating inventions - clamping mechanisms for aircraft interiors, rainproof solutions for aircraft and new actuation technologies - (TRL I).
- Creating a technology forecasting strategy - a way to set goals in management.
- Removal of technical contradictions that led to compromise (suboptimal) designs - (industrial research, II - IV TRL).

The classical view of TRL assumes that an invention idea (the beginning of TRL II) emerges spontaneously from basic research (TRL 1). TRIZ assumes that a solution idea is developed independently of the basic research.

5. The possibility of using TRIZ in commercialization processes

Most of the ideas that developers think might be useful to customers will never be realized. Their development into a final product will be stalled by a series of difficulties and problems. A study carried out in Denmark in the 1980s shows that of the patented solutions that were licensed 73% never went into production, and of the 30 licenses that were used for production few had a significant and only one a decisive impact on the turnover of the company (Hansen, 1995). The costs generated by failed ideas are a loss for the company, hence the need to look for ways to reduce them. If, on the other hand, problems of a purely organizational nature stand in the way of the creation of a useful product, it is a loss also for society and an opportunity cost for the entrepreneur. Companies cannot afford to give up on introducing new services and products or improving processes, as this may result in losing the market when the competition does it (according to the concept of breakthrough innovation). At the same time, an entrepreneur investing in innovation must take into account the risk of creating imitations by competitors. Imitations are produced at a cost of 65% of original research and with the help of 70% of original research time (Mansfield et al.,1981). Hence, the logical conclusion should be to keep the cost of creating innovations to a minimum. In the literature on TRIZ, there have been many proposals over the years to use TRIZ and attempts to modify TRIZ towards use for non-technical (organizational) problems.

Using TRIZ tools also allows you to get an idea with high functionality. This allows you to expect that it will be better received by the end customer The possibility of using TRIZ in commercialization processes appears on several levels.

5.1. Generating an innovative idea

A TRIZ tool to reduce the cost of basic research on solving a diagnosed problem is called functionally directed search (puf).

Instead of conducting research to obtain new product properties, we can look for a solution in other technical systems. The non-obviousness of the TRIZ tool lies in the process of generalizing the function we need from the originally diagnosed problem using another TRIZ tool, Cause and Effect Chain Analysis, similar to root cause analysis (i.e., finding the root problem through a series of questions), and then searching for technical systems for which these functions are key. A similar application, respectively, is the procedure called feature transfer, where we look for technical systems with needed useful features in our system.

Indicating the usefulness of TRIZ for improving existing products, let's analyze the case of the Boeing company, which tried to solve the problem of fading GPS signal on the aircraft (company website). Without going into the details of the developed solution, let us indicate the next steps of the process:

- Initial diagnosis of the problem.
- Attempting solutions by conventional means (unsuccessful).
- Application of TRIZ tools.
- Reformulating the problem by getting to the real cause.
- Laboratory verification of workshop findings.
- Implementation of the solution to the real cause of the problem (already without TRIZ).

5.2. Improving an existing product

The above indicates the usefulness of TRIZ for the correct formulation of a technical problem, improving the utility of the product to the end customer. Research can be used to develop a solution for such a diagnosed problem. TRIZ, in this view, is a tool that functions in the environment of the research process, however, necessary to formulate an economically useful goal for the scientific project and hence indirectly defining expectations of its research agenda.

5.3. Streamlining the commercialization process

Classical (technical) TRIZ is not directly suitable for organizational improvement, however, attempts have been made to transform it in depth and formulate a set of tools for solving organizational problems in management. One way of such transformation is to build a palette of available solutions for a manager based on known business cases. H.J. Harrington

(Harrington, 2017) formulated a comprehensive way to implement the tools of the so-called Lean TRIZ based on, among other things, his own experience in managerial positions in American organizations. In this way, he formulated a finite number of possibilities for improving processes in the organization with respect to the three objectives he defined. In this arrangement, each possible process change action has a positive, neutral or negative impact on one of the three defined objectives. In this way, a contradiction is formulated between the goals of the organization. Working out a solution to a contradiction, as in the original TRIZ, requires conducting workshops in the environment in which it is to be implemented. The 5 proposed tools include among others workshops for the elimination of sub-processes that do not create value for the customer. It seems worth exploring their application in relation to the commercialization process understood as a transition within a single company/research unit from basic research to the final product by presenting the processes-subprocesses on a map and then eliminating those that do not create value for the final product. The second application of Lean TRIZ is used to create or improve products in a reduced time compared to classical TRIZ.

5.4. Overcoming organizational barriers to commercialization

Classical TRIZ (as explained earlier) was not created with the intention to solve management problems, including those that arise during the commercialization process. However, some of the tools of the method can be used almost unchanged. Creating a chain of cause and effect defects (CECA) is an extension of root cause analysis (RCA) within TRIZ. The essence of the tool is to inquire through a series of questions what are the real sources of the diagnosed problem. At the end we can formulate them in the form of contradictions to be solved using the resource categories described in 'classical' TRIZ: time, space, system, environment (super system), information (Soukhov, 2007). A simple application of TRIZ to a business problem is to treat its tools as inspiration, rather than detailed rules and algorithms. Mann (triz-journal.com) proposes this view of the 40 inventive principles of technical TRIZ for developing one's own solutions to a given management problem. Importantly, the problem must be correctly formulated according to the same technique used for technical problems.

Importantly, the problem must be constructed in accordance with the technique used in the case of technical problems - that is, we define the state we want to achieve and then indicate what the obstacles are. The analysis of the proposed solutions by the author shows that the number of generated variants will depend on the knowledge of management issues. One should be aware that such an approach plays a role similar to the so-called ice-braker technique during meetings - it is supposed to break mental inertia and established ways of thinking about the problem. The author's interpretation of the 40 principles often changes the technical understanding of a term to a metaphorical use (e.g. atmosphere in terms of chemical composition changed to atmosphere in the organization). If one keeps in mind the obvious limitations of such a procedure then this use of the 40 inventive principles can be useful. In cases where the generated management solution is intertwined with the use of technology such a treatment may be closer to classical TRIZ, which was supposed to propose a generalized solution to a class of problems (e.g., if we talk about creating a virtual copy of some product for customer use, using a principle suggesting the creation of virtual copies in technical TRIZ). A major barrier to commercialization is the increase in costs at successive stages that bring an idea closer to the marketable product stage. TRIZ can be used to reduce the cost of solving business problems.

One of the ways may be to perform an analysis of resources derived from the classic TRIZ extended by human resources (Mueller, 2005) so that the solution can be developed based on the resources available to the company, not taken into account before the analysis, which gives a chance to reduce the cost of the developed solution.

6. Summary and conclusions

The article analyzes the role of TRIZ in the innovation process. A major barrier to commercialization is the increase in costs at successive stages that bring an idea closer to the marketable product stage. TRIZ can be used to reduce the cost of solving business problems.

First of all, TRIZ assumes that a solution idea can be developed independently of the basic research.

Using TRIZ tools also allows to get an idea with high functionality and expect that it will be better received by the end customer.

The possibility of using TRIZ in commercialization processes appears on several levels:

- A TRIZ tool to reduce the cost of basic research. Instead of conducting research to obtain new product properties, we can look for a solution in other technical systems.
- TRIZ is a tool useful to formulate expectations towards research agenda.
- Lean_TRIZ could be potentially useful for streamlining commercialization process. The second application of Lean TRIZ is used to create or improve products in a reduced time compared to classical TRIZ.
- Creating a chain of cause and effect defects (CECA) could be useful for resolving commercialization process problems.
- TRIZ resources analysis tool extended by human resources gives a chance to reduce the cost of the developed solution.

TRIZ approaches presented in the article are primarily an attempt to move away from a purely intuitive approach to the problem of creating innovations and managing the problems of the commercialization process to standardized methods, providing starting points for development within the own work of research and management teams. Their application gives hope for faster and cheaper development of a more useful innovation for the customer.

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