Chapter 3
Application of Design Thinking and TRIZ Theory to Assist a User in the Formulation of an Innovation Project

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Abstract The main limitations of Design Thinking lie in its high subjectivity, the presence of psychological bias, and the lack of focus in the idea generation phase. Furthermore, it does not offer strategies or techniques for the specific solution of the inherent problems in the design process, aspects that the theory of inventive problem-solving or TRIZ can cover by approaching the problem in the form of a contradiction. The employment of TRIZ within the Design Thinking process has the potential to facilitate the generation of alternative solutions through the principles of separation or the contradiction matrix. On the other hand, TRIZ does not consider to a large extent the user for whom one designs, an aspect that is fundamental in design thinking. Consequently, the combination of the capacities of both approaches can generate a complementary structure to approach the design process. This paper describes a basic structure to combine the best characteristics of both approaches to channel creative thinking and efforts during the development of an innovation project.

Keywords TRIZ · Design thinking · Product design · Innovation

3.1 Introduction

If a company wants to maintain its competitive position in the present market, it must make an effort so that its products and services meet the needs and desires of consumers. The success of a product (either manufactured or service) in the market will depend on the correct identification and assimilation of these requirements.

Therefore, the manufacturer's starting point for the design of a new product or the modification of an existing one lies in the capacity it presents for identifying present and future market demands with the highest possible degree of accuracy.

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Therefore, the organization must be agile and efficient enough to capture what are the needs and requirements of the users and materialize them in a product to satisfy them. The Design Thinking (DT) methodology starts from a deep study and analysis of the user when they are interacting with the product, this process is called: Empathy, and its purpose is to detect the problems that it presents during that experience, to later enunciate a series of probable solutions and finally, select the one that most efficiently solves the problem.

Despite the usefulness of DT, this approach does not propose specific tools to deal with problems that are always associated with the design process. A method based on the evolution of technology offers a series of concepts and tools to solve problems: the Theory of Inventive Problem Solving (TRIZ). Despite its ability to model and solve problems, TRIZ does not have in its structure a tool to identify market needs. This task is based on an individual's experience and knowledge of using other tools.

Therefore, both methods are complementary: DT produces valuable information to guide the design effort, while TRIZ provides an effective and repeatable toolbox for problem-solving. Thus, this paper proposes a framework to combine the advantages of both methods and demonstrate the usefulness of this combination to provide new resources with the potential to be used in the design of new products.

This chapter proposes five sections, the first one describes the design thinking methodology process, in which its basic concepts are cited, accompanied by an analysis of its state of the art, to observe how DT has been used during the design and development of new products or the modification of existing ones in different organizations.

Subsequently, a brief analysis of the Theory of Inventive Problem Solving (TRIZ, by its Russian acronym) describes the basic concepts, explores its usefulness in problem-solving processes, and underlines the bases that support it. Also, a review of the state of the art is presented to observe how it is used during the product design process and the resolution of engineering problems.

Once the reader becomes familiar with the concepts, we proceed to describe the integration of Design Thinking (DT) with the TRIZ theory, indicating which elements of TRIZ will be incorporated into the different phases of DT.

Finally, the last section proposes a case study to observe the feasibility of the DT+TRIZ integration, and its applicability during the design of new products, the transformation of existing ones, and the resolution of problems in the industry.

3.2 Innovation

An innovation is the introduction of a new, or significantly improved product (good or service), a process, a new marketing method or a new organizational method to the market and society (Oslo Manual 2005). In order for a business organization to develop a new product or improve an existing one within its portfolio, there are various design methodologies that establish a series of procedures, tools, and techniques to generate new proposals. Below, two of these design methods are exposed, the design thinking model, which has a strong position in the business ecosystem to design products and their easy applicability, and the TRIZ theory, which stands out in solving engineering problems, recognized for the high training that users of this methodology must have.

3.3 Design Thinking

3.3.1 Definition

It is a method of designing products, using the designer's way of thinking, which uses a type of unconventional reasoning in the business world, that is, deductive thinking. Therefore, the designer seeks the formulation of questions through the understanding of phenomena. In other words, questions are generated that must be answered from the information gathered during the observation of the universe surrounding the problem. Therefore, when thinking deductively, the solution does not derive from the obstacle: more precisely, it fits into it (Vianna 2016). There is a wide debate in the design community about who was the first author to coin the term "Design thinking", where a group attributes it to Herbert Simon (1978 Nobel Prize in Economics), and on the other hand to Peter Rowe, a renowned professional in the field of architecture and urban design, he served as a professor at Harvard University and published the book: Design Thinking in 1987. However, its massification and positioning as a methodology for product development and improvement are due to Tom Kelly and Tim Brown, co-founders of the international design and innovation consultancy IDEO, who disseminated the five-stage process (empathy, problem definition, ideation, prototyping, and evaluation) best known in entrepreneurship and design ecosystems.

3.3.2 Stages that Make Up the DT Process

The DT model of the Design Institute of Stanford University, the most widespread in the business and entrepreneurship ecosystem, is described below (Hasso Plattner Institute of Design at Stanford 2009):

Empathy: Empathy is the foundation of DT. To achieve this, it is necessary to carry out the following actions: (1) Observe the behavior of users in the context of their lives while using the product. (2) Interact with users and interview them through scheduled meetings and "intercept" them. (3) Experience what the user experiences while interacting with the product. The designers of the solution must understand people to transform this observation into knowledge and later into a product. The designer interprets and infers information about the meaning of the data obtained to discover ideas or perceptions. These perceptions channel the creative effort to generate solutions that satisfy their needs, requirements, and desires.

Definition of the problem: This stage summarizes the findings gathered through empathy and defines a specific and relevant problem. The objective is to define the problem or problems that the team must address and establish the evaluation criteria. It is also at this stage that the work team formulates design constraints and plans the evaluation metrics to validate a concept.

Ideation: This stage requires creative effort. The team needs to direct their creative efforts to come up with concepts that solve the design problem. Traditionally, this stage uses psychological tools such as brainstorming, six thinking hats, and lateral thinking, among other available techniques. The ideation stage is the transition from problem identification to the exploration of potential solutions. The team leverages collective perspectives, strengths, and creative effort.

Prototyping: A prototype is the first representation of what the product will look like, it can be a physical structure, sketches on paper sheets, simulations in software, and it can even be represented by means of a role-play or a recreation of some situation if we refer to a service. Its objective is that the development team can put it to the test and, most importantly, that it be provided to the user in order to be manipulated by them.

Evaluation: Qualification and quantification of the prototype, its performance is rated in the context of the user, feedback is collected from the user, in order to determine if their needs and requirements have been met or otherwise repeat the process in order to generate another proposal.

3.3.3 Design Thinking: State-of-the-Art Review

By analyzing the state of the art of Design Thinking, the following conclusions arise about this design approach:

One of the main strengths of design thinking is the ability to communicate ideas and create value proposals with multidisciplinary teams (Geissdoerfer et al. 2016; Brown 2009). Design Thinking has been increasingly recognized as a promising asset for fields other than design. It gained attention in the sectors of business, leadership, and management, as an option to deal with the growing complexity of the market and to be used as a source of innovation and commercial success (Davis 2010; Dorst 2011; Fraser 2007).

Design Thinking allows anyone without design experience to create solutions to everyday challenges. These solutions may be products, services, environments, organizations, and modes of interaction. The design team converges to transform the collected information into meaningful ideas (Shapira 2015). Principles that characterize DT according to Glen (2015):

- It is centered on the being. It tries to develop new knowledge about the problems faced by users in everyday life. It is necessary that the designer puts aside preconceived ideas and be willing to observe to define which problems deserve further investigation. It develops empathy.
- Observation. To understand human needs, the DT emphasizes observation that at the same time leads to empathy, understanding, and analysis. The purpose is to obtain an understanding of the user's requirements.
- Display. The approach used to make information meaningful. It takes advantage of empathy and intuition.
- Prototyping. The idea is represented with the purpose of obtaining feedback and learning. To generate many disposable prototypes, in the fastest and cheapest way possible.

According to Volkova and Jakobsone (2016), one of the most effective strategies to improve competitiveness is achieved by creating new products, with meaning, with added value and through the personalization of products taking into account the following aspects:

(a) The understanding of the identity and culture of the user.
(b) The requirements currently requested.
(c) Future trends.

DT has become an integral part of the innovation process. In fact, it plays a strategic role in the generation of value through the creation of ideas that respond better to the expectations and needs of consumers.

Design thinking with its broad and generic applicability provides an efficient method for the creation of value-added products effectively (Brown 2008); justifying in this way their ability to be integrated into other techniques, such as TRIZ.

DT involves solving complex problems that require curiosity, imagination, and creativity to generate, explore, and develop possible solutions, with value for the final user (Dorst and Cross 2001). It offers to companies the ability to transform products, services, processes, and strategies, where the last one determines new forms of value (Brown 2008).

DT defends the importance of empathy with the consumer. To develop good solutions, teams need to understand their users; how they think and what they feel about the problem that the group seeks to solve. DT offers a set of techniques about how to develop the ability to become empathetic with the users. It suggests the innovation teams to immerse themselves in the lives of their users and observe how they interact with the products they want to improve. By watching, listening, and collecting stories, they can capture unexpected ideas or longings. In line with DT's approach, innovation teams need to know their users and care about them and their lives to create meaningful products (Brown 2009).

The flexible application of Design thinking provides an effective method for creating value-added products effectively (Brown 2008). However, its flexibility of application implies that the expert who applies the DT is in need of solving problems outside his area of expertise. Consequently, it is necessary to aggravate the

DT deployment process with a method capable of formulating and solving problems in multiple domains. The Theory of Inventive Problem Solving (TRIZ) has this competence. The next section explores the use of TRIZ in the innovation process.

3.4 Theory of Inventive Problem Solving (TRIZ)

3.4.1 Definition

The TRIZ theory is an empirical, constructive, qualitative, universal methodology for generating ideas and solving problems, primarily when projecting engineering systems, on the basis of contradiction models and methods to solve them that were extracted from known inventions (Orloff 2012). TRIZ is a systematic, knowledge-based, and human-oriented methodology of the inventive problem-solving (Savransky 2000). TRIZ is the Russian acronym for the Theory of Inventive Problem Solving, developed by Genrich Altshuller. Its objective is to solve inventive problems and the intensification of creative and technical thinking. An inventive problem is the one that contains at least one contradiction (technical or physical), in which the conditions of the problem do not allow negotiation or compromise between the different parties to the conflict (Cortés 2003).

3.4.2 Basic Concepts of TRIZ

Contradictions: It is a situation that emerges when two opposite demands must be met in order to provide the result required. A contradiction is argued to be a major obstacle to solve an inventive problem, two types of contradictions are known in TRIZ: (1) Engineering and (2) Physical (Chechurin 2016). (1) Physical conflict: It is a situation that emerges when a certain attribute of a material object (represented as a substance or a field) must have two different (or opposite) values at the same time to provide the result required. An attribute can be a physical parameter, aggregate state, location, etc. (2) Engineering contradiction: It is a situation that emerges when an attempt to solve an inventive problem by improving a certain attribute (parameter) of a technical system leads to an unacceptable degradation of another attribute (parameter) of the same system.

According to TRIZ, often the most effective inventive solution to a problem is the one that overcomes some contradictions. A contradiction shows where (in the so-called operative zone) and when (in the so-called operative time) a conflict happens. Contradictions occur when improving one parameter or characteristic of a technique negatively affects the same or other characteristics or parameters of the technique (Savransky 2000).

Contradiction matrix: It is a matrix that provides systematic access to the most frequently used inventive principles to resolve a specific type of technical contradiction. In the contradiction matrix, a specific type of technical contradiction is selected by the predefined typical engineering parameters (Chechurin 2016).

The separation principles: Often a subsystem must perform contradictory functions or operate under incompatible requirements, in TRIZ such a situation is known as a physical contradiction (Savransky 2000). There are four separation principles for the resolution of physical contradictions: (1) Separation in space, (2) Separation in time, (3) Separation under conditions, and (4) Separation between the whole and its parts.

The 40 Inventive Principles: It is a set of generic solution proposals applicable in various industries. They are tips for finding highly creative and patentable solutions for solving your technical contradictions, that is, the problem in question.

Ideal system: The "ideality" of a system is the measure of how close it is to the perfect system. The perfect system (called the "ideal final result" in TRIZ) has all the benefits the customer wants, at no cost, with no harmful effects. So, a system increases ideality when it gives you more of what you want or less of what you do not want, does it at a lower cost, and usually with less complexity (Rantanen and Domb 2008). The Ideal Final Result (IFR) is the absolute best solution to a problem for the given conditions (Savransky 2000).

Resources: According to TRIZ, are things, information, energy, or properties of the materials that are already in or near the environment of the problem. If they can be used directly or modified to make them useful, the problem will appear to have solved itself. Think of the resources as the reserves they are invisible at first because we are accustomed to not seeing them when we look at the problem situation, but we can mobilize these reserves to solve the problem (Rantanen and Domb 2008). Resources can consequently be grouped in accordance with the following descriptions: (1) Natural or environmental resources, (2) Time resources, (3) Space resources, (4) System, (5) Substance resources, (6) Energy/field, (7) Information resources, and (8) Functional (Savransky 2000).

Psychological inertia: The resistance to thinking in a new way. By analogy to physical inertia, thoughts continue in the same pattern unless disrupted by a force.

3.4.3 TRIZ Benefits

Good solutions have several common features. The good idea does the following:

- Resolves contradictions
- Increases the "ideality" of the system
- Uses idle, easily available resources
- In addition to their everyday meanings, these words have specific technical meanings in TRIZ.

By working with the TRIZ concepts, you will learn to apply them to your problems, develop good solutions, and select the best solutions from all that are proposed (Rantanen and Domb 2008). TRIZ is unique because using the techniques relatively small number of easily understood concepts and heuristics (supported by effective knowledge databases), one can solve problems of any of the classes (Savransky 2000):

1. Improvement or perfection of both quality and quantity (considered Contradiction Problems in TRIZ)
2. Search for and prevention of shortcomings (Diagnostics)
3. Cost reduction of the existing technique (Trimming)
4. New use of known processes and systems (Analogy)
5. Generation of new "mixtures" of already existing elements (Synthesis)
6. Creation of fundamentally new technique to fit a new need (Genesis).

Perhaps in the twenty-first century, an additional component—the maximum speed of development and introduction of next-generation products will determine global economic leadership. If such is the case, then TRIZ takes on even more importance because it enables its practitioners to quickly obtain very high-quality and even breakthrough conceptual Solutions and then effectively remove technical obstacles in implementing the solution (Savransky 2000).

3.4.4 TRIZ: State-of-the-Art Review

A review of the literature about the benefits that the Theory of Inventive Problem Solving confers to the innovation process, its ability to be combined with other techniques, and its role in the New Product Development process.

TRIZ is a different method to conceive new products and processes that use various tools that propose several ways to propose inventive solutions (Altshuller 1999; Vaneker and Van Diepen 2016). It is a problem-solving approach strongly based on the concept of "Contradiction" using specific techniques to solve them (Fiorineschi et al. 2018).

TRIZ is compatible with the solution of problems, prevention of failures, and incidents, management, the creation of new products/services, the definition of commercial concepts, and the resolution of administrative conflicts. Therefore, it contains a set of tools to be conveniently selected, according to specific needs (Vaneker and Van Diepen 2016).

Creativity is the ability to generate new and useful ideas to overcome limitations in the generation phase of solution proposals, (Eppinger and Ullman 2007), as well as, (Ilevbare et al. 2013) suggest the application of specific methods and/or tools to support the idea generation stage. One of these "assistants" to creativity is TRIZ, which is considered to support designers in the generation of creative solutions.

3.4.5 *Reason for DT+TRIZ Integration*

After analyzing the strengths and weaknesses of each of the methodologies mentioned above, it was demonstrated that there is room for improvement to integrate the TRIZ theory into the DT process. The objective of the integration is to assist a user, a team of designers or a business organization in the formulation of innovation projects to design new products or improve existing ones by combining the best characteristics of both methods. Therefore, it is feasible to propose a framework with which products can be developed or improved through a five-stage process typical of DT (empathy, problem definition, ideation, prototyping, and evaluation) and the fundamental concepts of TRIZ, which are intended to guide a team or individual in the process of solving the intrinsic problems generated by the design process and thus channel creativity, imagination and thought processes of users.

After identifying the main contributions of each method, Table 3.1 summarizes the advantages of each approach and its complementarity.

As shown in the previous table, both methods complement each other to cover their deficiencies, DT benefits from TRIZ to identify, define, and model a problem, it provides an efficient toolbox for the detailed resolution of these problems, on the other hand, TRIZ benefits from DT to identify the requirements, needs, wishes, and emotions of the user for whom a product is being designed or improved, likewise, it guides the design process in an organized way through its five stages of easy interpretation and execution. Consequently, a framework is obtained to channel the thinking and creative effort of the development team toward the design of solutions that satisfy the user or consumer.

In conclusion, it can be mentioned that the complementarity of both methods allows the design of a framework with highly technical and humanistic characteristics, which efficiently directs intellectual capital during the design process, suitable to be adopted by some business organization or individual, that has as objective the design of new products or the improvement of an existing one in order to satisfy the end user.

Table 3.1 Complementarity between TRIZ and DT

Advantages	DT	TRIZ	DT+TRIZ
It identifies a user's requirements	Yes	No	Yes
It models an innovation problem	No	Yes	Yes
It proposes tools to solve problems	No	Yes	Yes
It offers a framework to guide the design	Yes	No	Yes
It subjects the proposed solution to evaluation	Yes	Yes	Yes
It contemplates the possible evolution of a product in the future	No	Yes	Yes
It can be used by users without design experience	Yes	No	Yes
It gives meaning to the products that are being designed	Yes	No	Yes
It prototypes to evaluate the proposed solutions	Yes	No	Yes

3.5 DT+TRIZ Framework

Figure 3.1 presents which foundations of the TRIZ theory are integrated into a certain stage of the Design Thinking model.

3.5.1 Description of the Framework DT+TRIZ

Below, the structure that makes up the DT+TRIZ framework is explained, which consists of the five stages of DT with TRIZ foundations integrated throughout the process, which aims to guide a user or team of product design in the formulation of an innovation project.

Stage 1: Empathy

The first stage of the DT method is called "Empathy" and is the basis of the entire design process since its primary objective is to understand the user for whom a product is designed. It is of utmost importance to carry out a wide and efficient investigation. Since the more information about the user, client, or consumer for whom the product is being designed is obtained, the greater the amount of material that is available for the generation of a solution that meets their needs, wishes and requirements will be.

This stage is also known as "Immersion" since the user of this framework (the designed or development team) has fundamental tasks to manipulate and experience

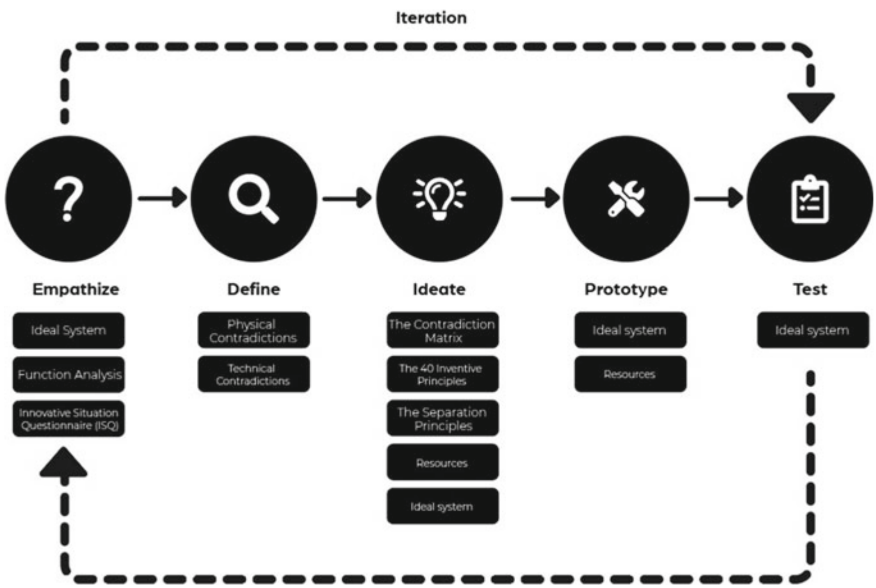

Fig. 3.1 DT+TRIZ framework

the product to be improved, as well as to try to get to know the users or customers of the product to understand their problems, requirements, emotions, and wishes. The elements of the TRIZ theory that are integrated into this section are: (1) Ideal system, (2) Functional analysis, and (3) Innovative situation Questionnaire (ISQ).

The objective of this section is to discover if the user or customer experience with the product is positive or negative, the context, the environment and routine in which they use the product. Furthermore, to observe if the user strictly follows the recommendations or has found situations to use it in a different way.

The methods used in the empathy stage can be classified by the type of information that can be collected: qualitative methods (observation, interviews, group dynamics) and quantitative methods (surveys and questionnaires) (Garreta and Mor 2010).

Results of Stage 1

The objective of this stage is to obtain user information in a concise way: tastes and preferences, environment in which they operate, routine, requirements, and desires. Knowledge about users, their contexts of use, objectives, and attitudes are essential for a user-centered design (Garreta and Mor 2010).

When implementing the ideal system concept at this stage, it is sought that when the user is describing their experience with the product or in what way they imagine the product does not exist (new product design), they should mention what elements, characteristics, and benefits that product must present so that it is 100% satisfied, that is, what functionalities and capabilities the product must possess in order to solve its problem or requirement.

To guide the interview with the user for whom it is being designed, the innovative situation questionnaire (ISQ) will be used. For the purposes of the practical case presented in this chapter, the version of the company Innovation Management and Sustainable Technologies, an innovation consulting firm, (IMST 2020) will be used. This tool is intended to effectively obtain the following information from the user: (1) Information about the system (product), (2) Information about the problem situation (with the product), and (3) Information about changes in the system (product). To reinforce Sect. 3.1 of the ISQ, the functional analysis will be used, which consists of describing the current (or desired) structure of the product and its way of operating.

Stage 2: Definition of the problem

The second stage of DT is called "Definition of the problem". In this section, the development team already has a large amount of information collected because of their interaction with the user or client in the first stage. It is here where one proceeds to analyze the data obtained in order to understand them and determine what inconvenience the user presents with the current product and the reason why their needs and requirements have not been met so far.

The elements of the TRIZ theory that are integrated into the second stage of DT are the physical and technical contradictions of the system. To efficiently delimit the needs and requirements of the user, the format is used to identify the characteristic that must be improved, in which: (1) The product is named in the form of a technical system, (2) The primary objective is defined of the system, (3) The parts and functions that make up the system are listed, (4) It describes how the system operates, and (5) It determines the characteristics that must be improved or eliminated. Similarly, the format for the formulation of the contradiction is used, which aims to guide the user to identify the properties that improve and worsen during the development process (Cortés 2015). The result is the identification of the physical or technical contradiction that will have to be resolved in the third stage of the process (Ideation).

Results of Stage 2

The main objective of this section consists of the correct identification of the physical or technical contradiction that the system (product) presents, with the support of the format for the identification of the characteristic that must be improved. The aspect or property of the product that must be resolved or modified for the user's satisfaction will be indicated.

Subsequently, through the format for the formulation of the contradiction, the characteristics that worsen during the process will be identified to achieve the property or characteristic that the user wants, in this way, the problem may be posed in the form of a technical contradiction, converting these characteristics or properties in technical parameters, which are required in the next stage (Ideation).

Stage 3: Ideation

The third stage of DT is ideation, it is in this section that a series of processes will be carried out to generate proposals for solving the problem, which was established in the previous stage. In this stage is where the greatest number of elements of the TRIZ theory accumulate among the five phases, in order to channel the thinking and creative efforts of the development team in the search for the solution to the problem.

The first concept of the TRIZ theory that is incorporated into the third stage of the DT is a contradiction, if in the previous stage (Definition of the problem) it is determined that the contradiction is physical, the separation principles are used in order to generate a solution proposal. There are four types: (1) Separation in space, (2) Separation in time, (3) Separation under conditions, and (4) Separation between the whole and its parts (Savransky 2000). On the other hand, if it is determined that the contradiction is technical, the matrix of technical contradictions is used, which consists of a tool that provides systematic access to the inventive principles used to resolve a specific type of contradiction (Souchkov 2018). The vertical elements of the matrix are the engineering parameters that need to be improved, while the horizontal columns contain the engineering parameters that may be affected or negatively degraded as a result of the improvement of the former, the numbers in the cells of the intersection guide the solution strategies (Savransky 2000), these elements are known as inventive solution principles, which make up a collection of 40 principles developed by Genrich Alshuller, the founder of TRIZ, the product of extensive studies analyzing thousands of inventions (Souchkov 2018).

In this section, the identification of the resources of the system (product) is carried out in the same way, according to Savransky (2000), these are categorized as follows: (1) Natural or environmental resources, (2) Time resources, (3) Space resources, (4) System resources, (5) Substance resources, (6) Energy resources, (7) Information resources, and (8) Functional resources. Their proper identification plays a relevant role during the design process since they can be used and generate a solution proposal to the problem. With these TRIZ tools, it is sought to best direct the creative effort of the development team in search of the ideal system to satisfy the user.

Results of Stage 3

The objective of this stage is to come up with solution proposals to resolve contradictions, make the best use of the resources available to the system and thus generate a product with the characteristics established by the ideal system, and therefore, satisfy the user.

In this section, four to six inventive solution principles will be identified (out of the 40 that exist) that aim to serve as a guide in the generation of solution proposals or system of improvement. Normally, a principle is retained to apply in solving the problem, however, the necessary ones can be used and even combined to develop a better proposal. Likewise, the system is carefully analyzed and it is determined with which of the 8 types of resources we can support ourselves to implement the previously selected solution. The entire ideation process aims to achieve the ideal system and thus satisfy the user. To determine which is the best solution among the different proposals that arise in this stage, stages four (prototyping) and five (evaluation) are required, which are explained below.

Stage 4: Prototyping

The fourth stage of DT is that of prototyping, which consists of the materialization of the proposals generated in the previous stage (ideation). If the system is a tangible asset, the device can be recreated using various materials (plastic, wood, cardboard, etc.) and even employ technology, such as 3D printing, while, if it is an intangible asset, such as services, role plays, storyboards, mockups, etc., can be used. The prototypes are provided to the user or client with the aim of manipulating and interacting with them in their daily context, to obtain feedback about the system. This should be built using resources and seeking to materialize in the best possible way the ideal system, TRIZ concepts that are part of this section of DT.

Results of Stage 4

The main objective of the fourth section is to take the solution proposals generated in stage 3 to a physical plane, experiment, and analyze their operation and performance, as well as to capture the reaction of the user or client and obtain feedback and flow of ideas.

Stage 5: Evaluation

The fifth stage of the DT is the evaluation stage, where the goal is to receive feedback from the client or user while interacting with the prototype. Thus, it will be determined whether the problems present in the system have been resolved and therefore satisfy the needs and requirements of the users, otherwise, another proposal must be presented to the user from among the various options generated in the third stage (Ideation), considering that the entire DT model is iterative, the process can be repeated as many times as necessary until the user or client is satisfied with the product provided, which in short, refers to approaching or reaching the ideal system, the TRIZ theory concept related to this last stage of DT.

Results of Stage 5

The main objective of this section can be summarized as determining whether or not the requirements, desires, and needs of the users for whom it is being designed have been satisfied, if the answer is positive, the product design process is concluded, otherwise, an iteration is carried out between the whole DT process as many times as necessary to get closer or achieve the ideal system established by the user and the design team from the first phase (Empathy). Qualitative and quantitative techniques are employed to evaluate the proposals.

3.5.2 Results of the DT+TRIZ Integration

The state of the art showed that the integration of DT and TRIZ is feasible. After analyzing the advantages and limitations of each tool, its complementarity was determined. DT provides TRIZ with accurate information about the requirements and wishes of the users for whom it is being designed. It offers a framework to guide the design process, even to be carried out by users with no design experience. In addition, it endows the product with significance to make it more attractive to the user. Consider prototyping to materialize the proposed ideas and thus facilitate interaction with the user. The proposals generated are submitted for evaluation to obtain feedback, and if necessary, to return to previous stages of DT, and thus to improve the prototype.

On the other hand, TRIZ gives DT the possibility to formulate a problem in the form of a contradiction. By implementing this strategy, it is possible to deploy the TRIZ toolkit to solve this kind of problem effectively. Therefore, DT sets a process to design products and establishes the base, which is the description of the user for whom one works, while TRIZ provides the necessary tools to channel the creative effort of the design team during the generation of potential solutions.

3.6 Case of Application: A Domestic Electrical Outlet Case for a Blind Person and Visual Weakness

The following case study shows how the DT+TRIZ framework was applied to make a proposal for improvement in a house-room electrical contact.

Stage 1: Empathy

In this first step, the Innovation Situation Questionnaire (ISQ) is useful to acquire valuable information and provides a broad perspective of a technical system (Terninko et al. 1999). The ISQ is a guide for obtaining information from the user, given its extensive dimension (17 questions). The next points show the information collected with this tool.

Information about the system (product/process)

– Electrical outlet (domestic): The primary useful function is to provide energy by contact. Also, to cover an electrical installation (electrical contact and general wiring of the house-room), while fulfilling an aesthetic function. The electrical system (1) provides electrical power to any device that is inserted into the holes through a plug, the case (2) has the function of covering the system and the electrical wiring and indirectly fulfills an aesthetic function (Fig. 3.2).

  The plug is inserted in the holes to provide electrical power to some devices, the case is responsible for covering and thus hiding the electrical installation and various wiring of the wall of the house-room.

– System resource: "Space" resource in the case, the case area is mostly unoccupied, and the space of the electrical contact holes uses small dimensions.

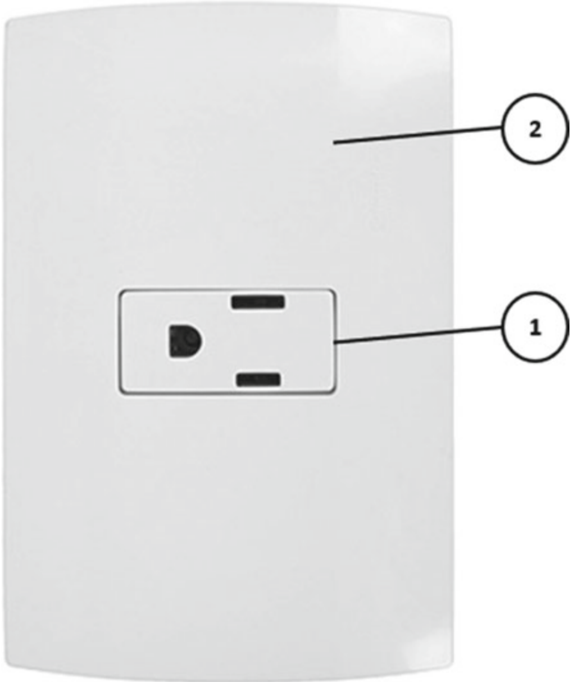

Fig. 3.2 Electrical outlet main parts

Information about the problematic situation

The area of the electrical contact holes is very small, which makes it difficult to insert a plug for a blind person, visually impaired, and even a user who simply wants to insert a plug and the place is dark or poorly lit, which turns a simple activity like inserting a pin into the socket into a cumbersome task.

Information about system changes

According to several standards (The International Electrotechnical Commission-IEC, The American National Standards Institute-ANSI, and Normas Oficiales Mexicanas-NOM, among several others), the dimensions of the contact holes cannot be increased. The adequate electrical power supply of the contact must not be compromised. The electrical installation of the house-room should not be left exposed. The electrical contact is surrounded by a case, it is possible to make modifications in the area to achieve the desired effects.

Stage 2: Problem definition

Technical contradiction

Identification of the feature to be improved

1. Name of the technical system (TS): Electrical contact outlet.
2. Define the primary objective of the TS: It is designed to provide electricity through the contact of two metal pieces, it also covers an electrical installation, and fulfills an aesthetic function.
3. List the main elements that make up the TS and their functions:
   (a) Electric contact: Transmit electrical energy.
   (b) Exterior cover: Cover an electrical installation.
4. Describe the operation of the TS: The contact transmits electrical energy to the inserted plug and through it provides power to a device. The case covers the electrical installation (electrical contact and general wiring of the house-room), fulfilling at the same time an aesthetic function.
5. Determine the features that need to be improved or removed: The case, in addition to covering the wiring of the house-room and serving as a decoration, must facilitate the insertion of the plug for blind people, visually impaired, or in a dark house-room.

Formulation of the contradiction (improvement)

Define the feature to be improved:

(a) The characteristic is: The space to insert the plug should be wider.
(b) Mention the means used to carry out this improvement: Use the case to drive the pin into the holes.
(c) Mention which is the characteristic that worsens under the conditions present in 1b: The shape of the case.

(d) Formulation of the technical contradiction: If the case of the electrical contact is modified to direct the pin into the contact holes more easily, then the usual shape of the electrical contact is affected.

The technical contradiction explains that it is necessary to increase the area of a stationary object, but the present shape does not allow this modification. This contradiction is present in the Contradiction Matrix, and then, useful in the ideation stage.

Physical contradiction

The object must be large to facilitate the insertion of the plug, but small to complain with international standards.

Stage 3: Ideation

Technical contradiction solution

This stage aims to propose possible solutions in such a way that the systems get closer to their ideal state (Altshuller 1999). It is stated that the technical contradiction refers to the fact that if the area of the system is improved, then the shape of the system worsens, so the Contradiction Matrix is used to propose a solving strategy. Savransky (2000) and Rantanen and Domb (2008) offer a detailed description of this tool (Fig. 3.3).

The technical contradiction isolates a set of inventive principles: 17, 5, 4, 7, and 28. This case study uses the Contradiction Matrix 2003 (Zlotin et al. 2003), which proposes a matrix where all rows propose at minimum four inventive principles. If a user proposes a technical contradiction that calls for a contradiction in the diagonal

Worsening Feature → / Improving Feature ↓			Physical								
			Weight of Moving object	Weight of Stationary Object	Length/Angle of Moving Object	Length/Angle of Stationary Object	Area of Moving Object	Area of Stationary Object	Volume of Moving Object	Volume of Stationary Object	Shape
			1	2	3	4	5	6	7	8	9
Physical	1	Weight of Moving Object		3 19 35 40	17 15 8 35	15 17 28 12	28 17 29 35	17 28 1 29	28 29 7 40	40 35 2 4 7	3 35 14 17
	2	Weight of Stationary Object	35 3 40 2		17 4 30 35	17 35 9 31	17 3 30 7	17 14 3 35	14 13 3 40	31 35 7 3	13 7 3 30
	3	Length/Angle of Moving Object	31 4 17 15	1 2 17 15		1 17 15 24	15 17 4 14	17 3 7 15	17 14 7 4 3	17 31 3 19	1 35 29 3
	4	Length/Angle of Stationary Object	35 30 31 8	35 31 40 2	3 1 4 19 17		3 4 19 17	17 40 35 10	35 30 14 7	14 35 17 2	13 14 15 7
	5	Area of Moving Object	31 17 3 4 1	17 15 3 31	14 15 4 18	14 17 15 4		17 1 4 3	14 17 7 4	14 17 7 13	35 4 14 17
	6	Area of Stationary Object	14 31 17 19	35 14 31 30	17 19 3 13	17 14 3 4 7	4 31 7 19		17 18 14 7	14 28 26 13	17 5 4 7

Fig. 3.3 Fragment of the traditional MRCT that indicates the principles for the resolution of the contradiction area of a stationary object versus shape

of the matrix, this problem is in fact, a physical contradiction, and thus the separation principles are the best tool to use.

Recommended Principles

Principle 17. Movement into a new dimension

a. Remove the problems of moving an object on a line with movements in two dimensions (along a plane). Similarly, the problems of moving an object in a plane go away if the object can be changed to allow for three-dimensional space.
b. Use a multilayered assembly of objects instead of a single layer.
c. Tilt the object or flip it as it should be.
d. Project images on nearby areas or on the front of the object.

Principle 5. Combining

a. Combine in a space homogeneous objects or objects intended to operate continuously.
b. Combine homogeneous or contiguous operations in time.

Principle 4. Asymmetry

a. Replace a symmetric shape of an object with an asymmetric one.
b. If the object is already asymmetric, increase the degree of asymmetry.

Principle 7. Nesting

a. Contain the object inside another that is ultimately contained in a third object.
b. An object passes through the cavity of another object.

Principle 28. Replacement of mechanical systems

a. Replace the mechanical system with an optical, acoustic, or odoriferous one.
b. Use an electromagnetic, electric, or magnetic field for interaction with the object.
c. Replace the fields.
d. Use a field in conjunction with ferromagnetic particles.

Retained principle

After analyzing the principles cited above, it is determined that principle number 5 can be applied to solve the problem. The principle consists of combining objects in a space to operate continuously.

Solution implemented

The recommendation based on principle number 5 was applied. It is proposed to modify the area of the case to give it a funnel shape. This change assists the user to facilitate the insertion of the plug. Thus, the funnel shape will direct the plug toward the electrical contact holes, achieving the continuous operation effect described in principle 5. The case fulfills its initial function of covering the electrical installation and simultaneously directs the plug to the proper position to be inserted.

Physical Contradiction Solution

The separation principle suggested: separation in space. This principle recommends:

A. Attempt to split (actually or theoretically) the key subsystem into two or more subsystems.
B. Assign each conflicting function or opposing requirement to a different subsystem.

This principle of separation suggests that the system must be divided into two or more subsystems, which means that the case, besides fulfilling its function of covering the electrical installation, should direct the plug toward the holes in the contact.

Stage 4: Prototyping

The objective of this stage lies in the materialization of the solution proposals generated in the third stage (Ideation). The developed prototypes are shown (Table 3.2, Fig. 3.4, Table 3.3 and Fig. 3.5).

Stage 5: Assessment

To evaluate the two prototypes developed in stage four and select the one that has the characteristics of the proposed ideal system (or the one that is most similar to it) and meets the requirements stipulated by the user, an assessment matrix will be used. The assessment matrix consists of a measurement instrument to assess the performance of a series of specific criteria. The criteria that will be assessed in each of the prototypes are:

– **Functionality**: The casing fulfills the objective of facilitating the insertion of the plug in the contact holes.
– **Time**: It is possible to reduce the time in which a blind user, visually impaired, or in a dark room inserts the plug into the contact holes.
– **Security**: The casing continues to perform the important function for which it is designed, that of covering the electrical installation and wiring.

The Pugh evaluation matrix (Pugh 1991) and the results obtained when evaluating the two developed prototypes are shown (Table 3.4).

As can be seen, prototype 1 obtained a score of 2, while prototype 2 obtained 3 points. The foregoing indicates that the second prototype is the one that best covers

Table 3.2 Prototype 1

Prototype 1
The first prototype consists of sectioning the casing area in the form of a funnel, with a wide opening on the upper side, which is reduced as it approaches the contact holes, to channel the plug with the sole fact of contacting the case, in this prototype the usual vertical position of the contact is maintained.
Illustration

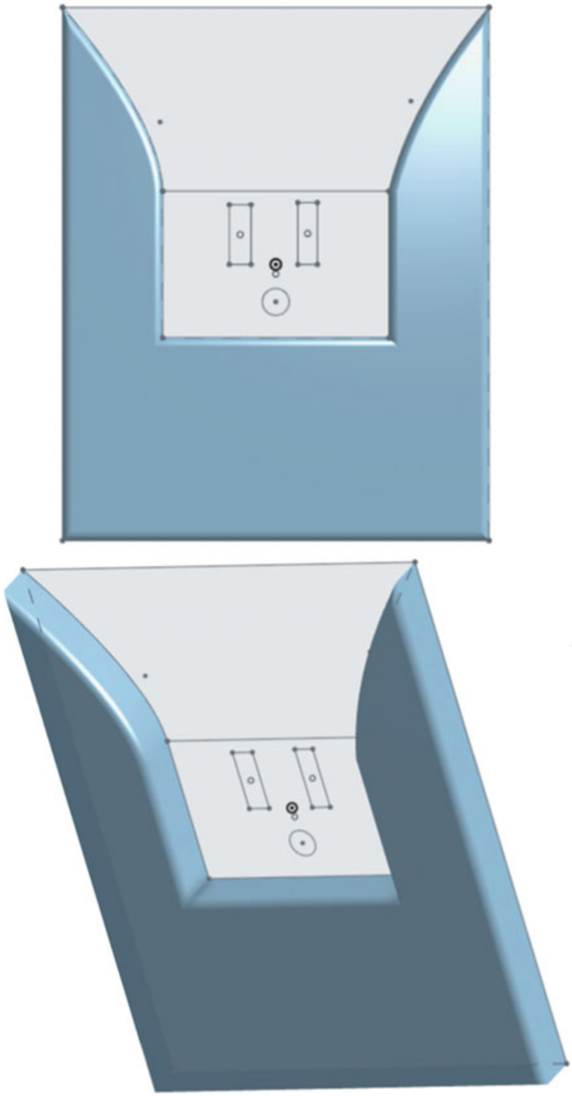

Fig. 3.4 Prototype 1, electrical contact case in vertical position

Table 3.3 Prototype 2

Prototype 2
The second prototype consists of sectioning the casing area in the form of a funnel, with a wide opening on the upper side, which is reduced as it approaches the contact holes, to channel the pin with the sole fact of contacting the case, in this prototype the usual position of the contact is modified, placing the case in a horizontal position.
Illustration

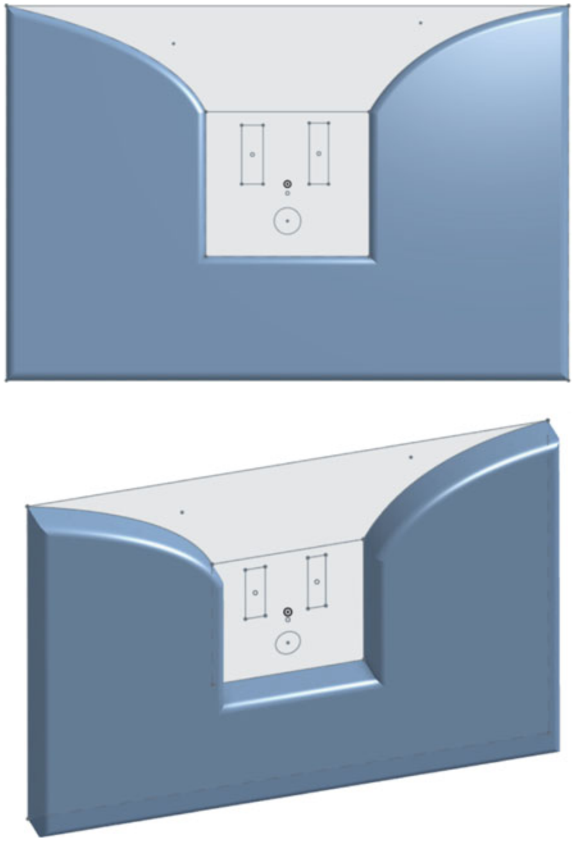

Fig. 3.5 Prototype 2, electrical contact case horizontal position

Table 3.4 Pugh matrix applied to prototypes

Criteria	Design alternative	
	Design	Design
Functionality	1	1
Time	0	1
Security	1	1
Positive sum	2	3
Negative sum	0	0
Total	2	3

the needs and requirements of the user, that is, the one that is closest to the ideal system, this being the one chosen as the final product.

3.7 Conclusions

The DT+TRIZ framework meets the objective of guiding the design process of new products and services, as well as the improvement of existing ones, being used by an independent designer, entrepreneur, or business organization, who has the initiative or commission to create a product that best meets the wishes and requirements of a user or customer. During its implementation, rambling, psychological bias, and creative blockages are reduced, increasing efficiency when generating solution proposals. Importantly, it provides the tools and elements necessary to argue why the proposed solution generated after the implementation of this framework is ideal for meeting market demands.

One aspect to highlight is the interest that the DT+TRIZ framework generated in the national and international academic community, since when it was disseminated in conferences through presentations, articles, and research stays, the topic generated interest in the attendees for the originality of integrating a methodology with highly technical characteristics such as TRIZ theory into a methodology with highly subjective characteristics, such as the DT process, which has been adopted by a large number of private companies, educational institutions, foundations, and the government to develop your products and services.

3.8 Future Work

It is contemplated to incorporate the trends of evolution into the framework to explain what the stages of development of a product will be. In this way, it will be possible to plan a family of products and to better manage its transitions.

It is considered to develop a mobile, web, and/or desktop application that contains the DT+TRIZ framework and guides the process of developing new products. Data mining, knowledge management, and artificial intelligence is contemplated for the development of this software.

Finally, it is necessary to continue disseminating this research and its respective results in scientific journals in the field of design, product design, and innovation management.

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