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Classifying TRIZ methods to speed up their adoption and the ROI for SMEs

Stefano Filippi *, Barbara Motyl, Fabio Massimo Ciappina

University of Udine, Department of Electrical, Management and Mechanical Engineering, Product Innovation Research Group - PIRG, Via delle Scienze 208, 33100 Udine, Italy

Abstract

The interest about TRIZ is increasing day by day in the Small and Medium Enterprises - SMEs. Many of them ask for solutions but sometimes they cannot manage the costs coming from a deep review of their design projects. Our research group is carrying on a project to customize the adoption of TRIZ by the SMEs. The goal is to speed up this adoption and to disclose the Return Of Investment - ROI - as early as possible. The project classifies and subdivides TRIZ methods in order to foresee the generation of solutions falling into different categories. This classification has been exploited and validated in the field thanks to the collaboration with a hi-tech SME, the Sei Laser Converting srl.

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1. Introduction and background

The interest about TRIZ is increasing day by day in the Small and Medium Enterprises - SMEs - of the Northeast Italy and it is founded on the effectiveness of the methods that constitute it [1,2,3].

Many SMEs ask for solutions but sometimes they cannot manage the costs coming from a deep review of their design projects. Moreover, the R&D departments of some SMEs are unable to follow all the suggestions coming from a full adoption of TRIZ at the moment. The universities and the research centers, working in synergy with industrial partners in order to maximize the knowledge about TRIZ and its exploitation, take much care about these peculiarities and tune their research, courses, and seminars accordingly.

The Product Innovation Research Group - PIRG - of the University of Udine is carrying on a project to customize the adoption of TRIZ by the SMEs. The goal is to speed up this adoption and to disclose the Return Of Investment - ROI - as early as possible.

* Corresponding author. Tel.: +39-043-255-8289 .
E-mail address: filippi@uniud.it .

One of the ways to get this goal consists in classifying and subdividing the TRIZ methods in order to foresee the generation of solutions falling into different categories. The main criterion to define these categories is the type of adoption in the system under analysis of the solution concepts found.

This paper first describes a set of TRIZ methods. Then it outlines this classification, aimed at distinguishing those methods and techniques that more often generate conceptual solutions preserving the existent system as much as possible, namely “redesign solutions”, from others that, on the contrary, require deep modifications and heavy redesign activities from scratch, specifically “design solutions”.

In the third section the research activities are summarized and the setting of the classification criterion is explained.

The results of this research have been applied in the field thanks to the collaboration with a hi-tech SME, the Sei Laser Converting srl. This company designs and manufactures machines and systems for digital converting and finishing, and develops integrated applications to innovate productive processes and applications in the packaging and printing fields. The fourth paragraph reports a case study based on the optimization of the gold alloy embellishment subsystem of a machine for label printing. The TRIZ adoption generated two sets of design and redesign solution concepts, with different requirements in terms of design efforts and costs. These differences and their formalization represent important information and an important decisional degree of freedom for the SMEs that would need and like to adopt TRIZ but that, up to now, have not, because of a scarce, poorly-organized knowledge about it.

2. TRIZ methods

During the carrying on of the project, quite all the TRIZ methods have been investigated, focusing on their roles in the TRIZ problem solving process and regarding the different kinds of solution they allow to achieve.

The application of the TRIZ techniques usually follows an iterative approach, based on a sequence of three main phases: the investigation phase; the abstraction phase, and the solution phase. This is important because the TRIZ methods are subdivided by the stage of their application within the TRIZ problem solving procedure, as reported in the following paragraphs.

In the investigation phase, the problem is described and analyzed. This phase exploits methods as the Innovation Checklist - IC - and the Resource Checklist - RC - [4,5]. These methods are considered good tools for collecting and organizing in a systematic way all the pieces of information concerning the specific system/problem under analysis.

During the abstraction phase, the specific problem is generalized and formalized. The methods used in this phase are: the Function Analysis - FA - [1,6], the Root Conflict Analysis - RCA+ - [1,7], the RelEvent Analysis [1,8,9], the Substance-Field - Su-Field - Analysis, and the Trends of Evolution [1,10]. In particular, the FA represents a fundamental method for the identification of system functionalities and for the description of the different functions of the system components. The RCA+ maps all causal chains of causes and effects that contribute to generate a problem and then allows identifying system conflicts, highlighting their connections with the super-systems [8]. The RelEvent Analysis considers the different process events and components. It represents a logical and temporal ordered sequence of actions and interactions that occur in the system/process [9]. This representation highlights the type of connections and the level of criticism of system components and super-systems. The goal of the Su-Field Analysis is to evaluate the relations between the components of the system. This goal is achieved by classifying the system components and the related super-systems into substances or fields. The result is a higher level abstraction, completely independent from the physical system analyzed. TRIZ Trends of Evolution [6,8,11] allow foreseeing the evolution of the system or process over time. This method is based on patents analysis and investigations.

Finally, in the solution phase, methods as Inventive Principles, the Contradiction Matrix and the 76 Standard Solutions are applied and evaluated [5,6,12,13,14]. TRIZ Inventive Principles are one of the pillars of the TRIZ theory and they are the base of the TRIZ problem solving strategy. These principles represent a set of solutions for solving general problems. These principles may be used alone, as a list of ideas and concepts, or in combination with the Contradiction Matrix. This matrix collects a set of possible contradictions which may be encountered during the analysis of the abstracted problem/system. A contradiction is the result of the crossing between an improving feature and a worsening feature. For each possible feature crossing, the matrix suggests the inventive principles that could be of help in solving the contradiction. These two methods are of simple use and may be used

mostly in case of redesign solution strategies. The 76 Standard Solutions and their application sequence are a systematic procedure for the resolution of technical problems. These solutions offer a wide range of possible solutions, related to different kinds of technologies and recovered from the solution of similar systems.

3. Research activities

3.1. Set of the classification criteria

As anticipated in the introduction, one of the main goals of this project is to classify the TRIZ methods in order to suggest the most suitable procedure according to the needs and capabilities of the interested SMEs.

The criterion has been inspired by the classification proposed by Eversheim in [4], where the TRIZ tools are subdivided in systematic tools, knowledge based tools and analogy tools. It reflects the use of the tools for different purposes during the problem solving process.

Moreover, another criterion to classify tools in categories has introduced here. It consists in the type of adoption of the found solution concepts in the system under analysis. First, it refers to the application moment within the TRIZ problem solving procedure has been done. Then, according to the use of the TRIZ methods during the three classical phases (investigation, abstraction, solution), it concerns the type of the solutions found. In this research, two levels of solutions have been considered: redesign solutions - solutions that can be easily integrated in the initial system, or design solutions, requiring a complete new design of the system or even its redefinition from scratch.

The classification resulting from the application of the two criteria can suggest the most suitable set of TRIZ methods given the needs of the SMEs, and encourage the dissemination of the TRIZ theory, methods, and tools.

3.2. Classification of TRIZ methods by phases and types of solutions

Accordingly to the proposed criteria, the TRIZ methods have been classified by their moment of adoption and by the type of solutions they allow to achieve.

Methods for the investigation phase

This way, during the investigation phase, the use of methods as the Innovation Checklist and the Resource Checklist was suggested. In fact, these methods allow a full and accurate problem/system analysis, and due to their general purpose, they may be applied both in redesign and in design solution processes. In fact, they enable to systematically collect information about the super-systems and about the functions and interactions of the system under analysis.

Methods for the abstraction phase

The FA allows a clear identification of the different functions of the system components in relationship to each other and to the whole system. FA generates a schematic description of the system under investigation. This way, FA may be considered a good example of abstraction not completely separated from the system under analysis, and it appears best suited both for design and redesign procedures.

The RCA+ is used for identifying the root of conflicts that arise in the system. Also, this method depends on the particular system under analysis and, again, the level of abstraction which can be reached by this kind of schematization suggests the use of RCA+ for both redesign and design solution processes.

RelEvent Analysis examines the events that occur in the system regarding the time and it gives functional information about the system process. The results of this inspection are quite completely disconnected from the system under analysis but also this method may be used in both redesign and design solution processes [1,8,9].

Su-Field Analysis allows a high level abstraction analysis of the system. The subdivision in substances and fields completely draws away the attention of the problem solvers from the specific system, and focuses their attention on what the system performs. Su-Field Analysis also allows classifying the interactions among the system components. This method usually suggests solutions of difficult integration in the original system and for this reason it is more suitable for processes that involve a complete new design of the system.

The Trends of Evolution are used to identify the current level of evolution of the system, and they may also suggest some possible evolutionary scenarios. This analysis is useful for design procedures, and in combination with

the Su-Field Analysis (by mean of which the abstraction of the system is reached) may suggest a scenario of what might be added to the system considering what is already present.

Methods for the solution search phase

Inventive Principles represent a set of good ideas ready to be used. Consequently, starting from a suitable level of abstraction of the system, the use of the Inventive Principles may give interesting suggestions for the particular problem encountered. The application is not particularly complex and usually it comes in combination with the Contradiction Matrix. The Contradiction Matrix collects and organizes the forty Inventive Principles in relation to contradictions. This way, once a system contradiction is identified (improving VS worsening features), the Contradiction Matrix suggests one or more specific inventive principles to be used for solving the conflict. For these reasons, these two methods appear suitable both for design and redesign.

The 76 Standard Solutions and their algorithm represent a well-structured method that, starting from the Su-Field diagram, always suggests a possible solution. The use of 76 Standard Solutions, in combination with the Su-Filed Analysis, suggests the adoption of this method during a design process, due to the high level of abstraction of the problem.

The results of the analysis described up to now are summarized in table 1.

	Investigation Phase	Abstraction Phase	Solution Phase
Redesign	Innovation Checklist Resource Checklist	Function Analysis Root Conflict Analysis RelEvent Analysis	Inventive Principles Contradiction Matrix
Design	Innovation Checklist Resource Checklist	Function Analysis Root Conflicts Analysis RelEvent Analysis Su-Field Analysis Trends of Evolution	Inventive Principles Contradiction Matrix 76 Standard Solutions

Table 1: Proposed classification of the TRIZ methods

4. Case study: Label printing problem

The proposed classification of the TRIZ methods has been applied in the field thanks to the cooperation with a hi-tech SME, the Sei Laser Converting srl, a part of Sei Laser group, located in the Centre for Technological Innovation at Amaro (UD). This company designs and manufactures machines and systems for digital converting and finishing, and develops integrated applications to innovate productive processes and applications in the fields of packaging and printing, mainly by the adoption of laser-source in the labelling systems.

This case study focuses on the optimization of the gold alloy embellishment subsystem of a machine for label printing.

Nowadays, this printing process is a well-known practice in the digital converting and finishing industrial field, and the state of the art of this technique concerns the use of a roll-to-roll system with a print matrix which compresses together the label tape to be embellished and the foil of the embellishment material, the gold alloy in this case.

The main drawback of this process is the notably generation of scraps of foil due to the complexity of the decoration to be printed. Sei Laser Converting srl was looking for a solution of the problem connected to the waste production in hot embellishment process. This problem requires a complex solution given the current printing process. For all these reasons, the company wanted to evaluate both design and redesign solution possibilities.

4.1. Case study activities

According to the proposed classification of TRIZ methods and to the needs of the Sei Laser Converting srl, the problem solving procedure has been subdivided in the three phases and both redesign and design solution have been considered, as described in the following paragraphs.

Investigation phase

In this phase the IC and the RC allowed a fast description of the printing process, of its super-systems and of all the system components with their spatial configuration. IC and RC have been set by means of interviews to two Sei Laser Converting srl expert technicians.

Abstraction phase

In this phase, the redesign solution approach has been considered first. The FA, shown in Figure 1, highlighted that the main problem of the printing process is connected to the foil. Nevertheless, the FA revealed some limitations because it was applied to a time dependent process.

The RCA+ analysis highlighted that the main conflicts occur during the printing process and it also gave clear information about the process super-systems. Figure 2 reports the RCA+ diagram.

Finally, Figure 3 shows how the RelEvent Analysis allowed the identification of the temporal sequence of the problems. As a result of the analysis done in the abstraction phase, it has been highlighted that the super-system represented by the foil limits the whole process; in fact, the waste of decorative material strictly depends from the foil itself.

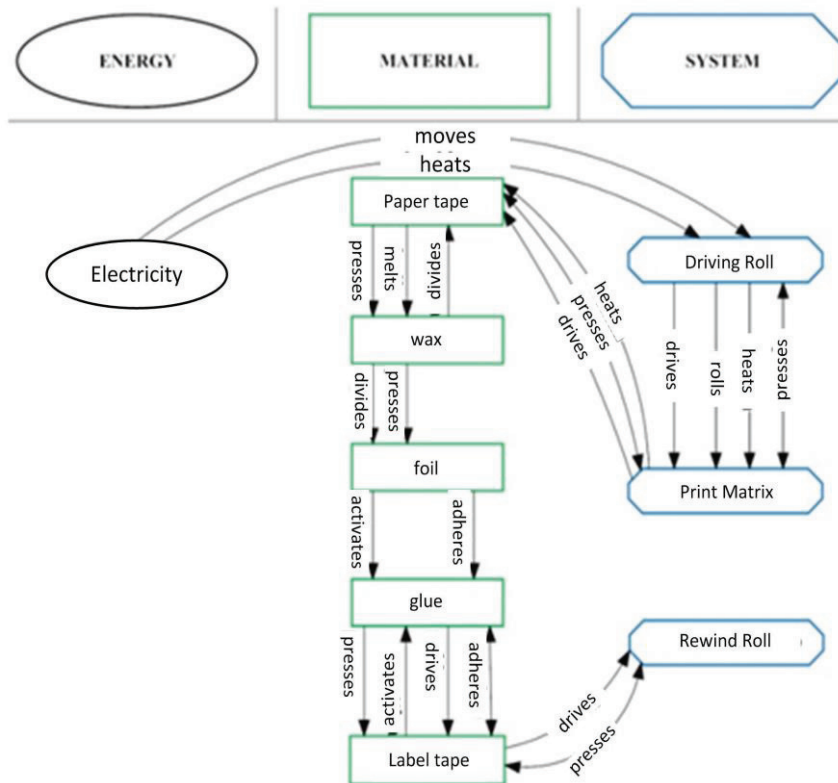


Figure 1: FA of the printing process.

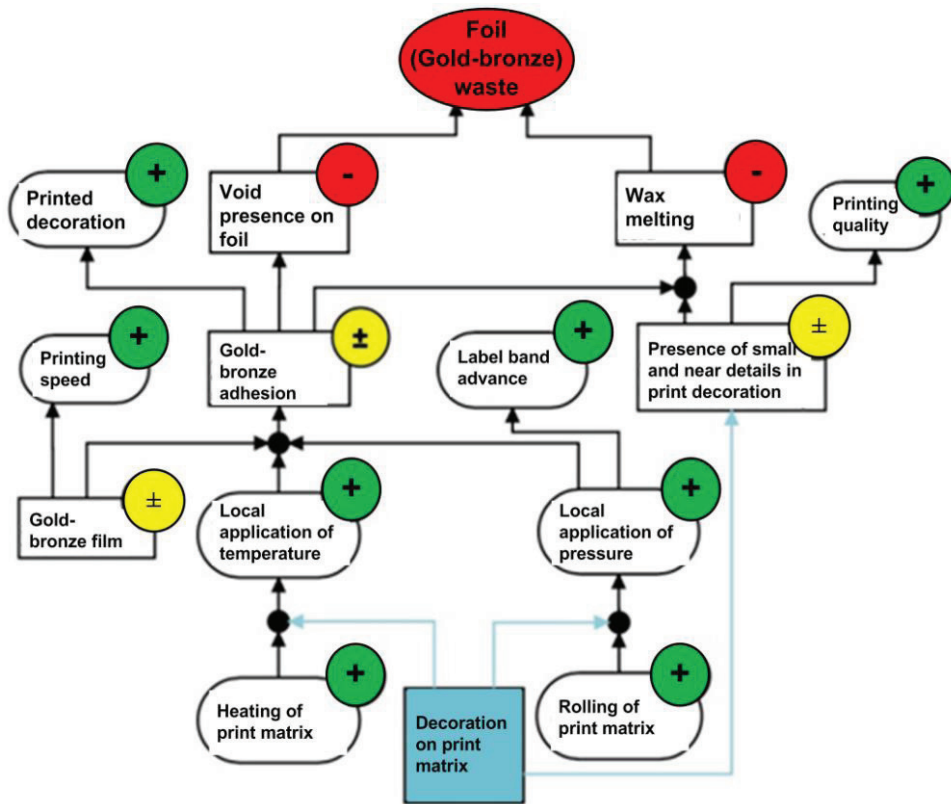


Figure 2: RCA+ diagram of the embossing printing process.

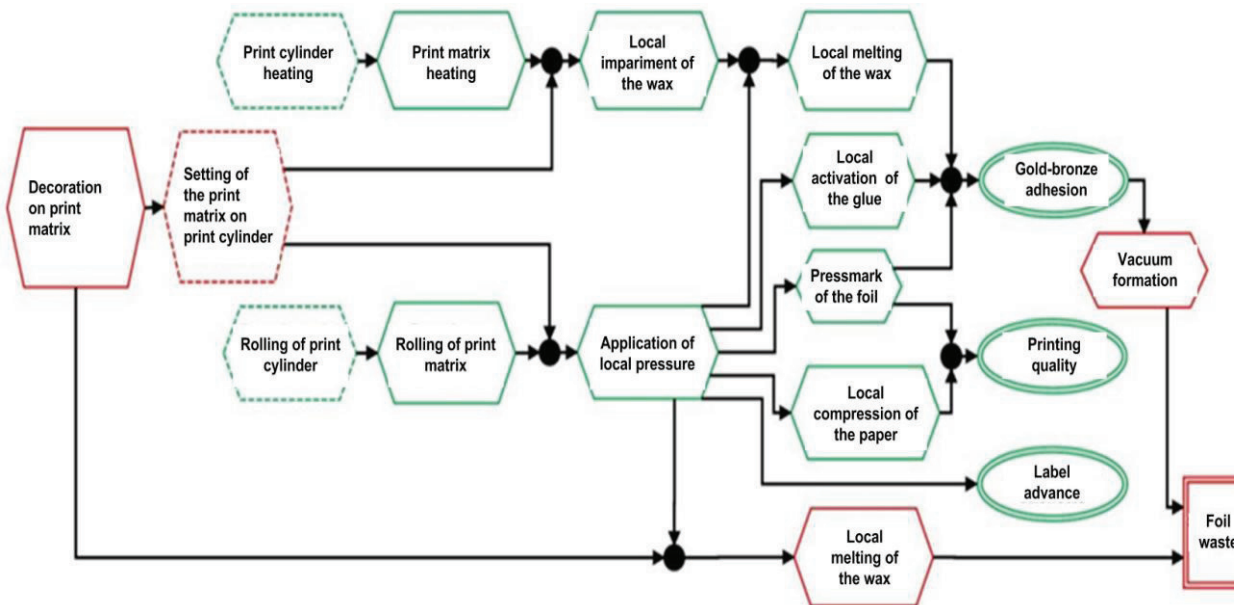


Figure 3: RelEvent diagram of the embossing printing process.

Regarding the search of design solutions, in the abstraction phase, the Su-Field analysis has been performed, as shown in figure 4. In particular, Figure 4a represents the system composed by driving roll, print matrix, rewind roll, foil and label band (S1, S2, S3). Then, in Figure 4b, the schematization is extended to highlight all the foil components interactions (S2 is split in S4, S5, S6 and S7 parts). Finally, Figure 4c represents the adhesion process considering the undesired wax fusion while in Figure 4d the correct adhesion procedure is modeled. This method allowed the exact identification of the system components that generate the problem, clarifying also their physical interactions with the other elements of the system.

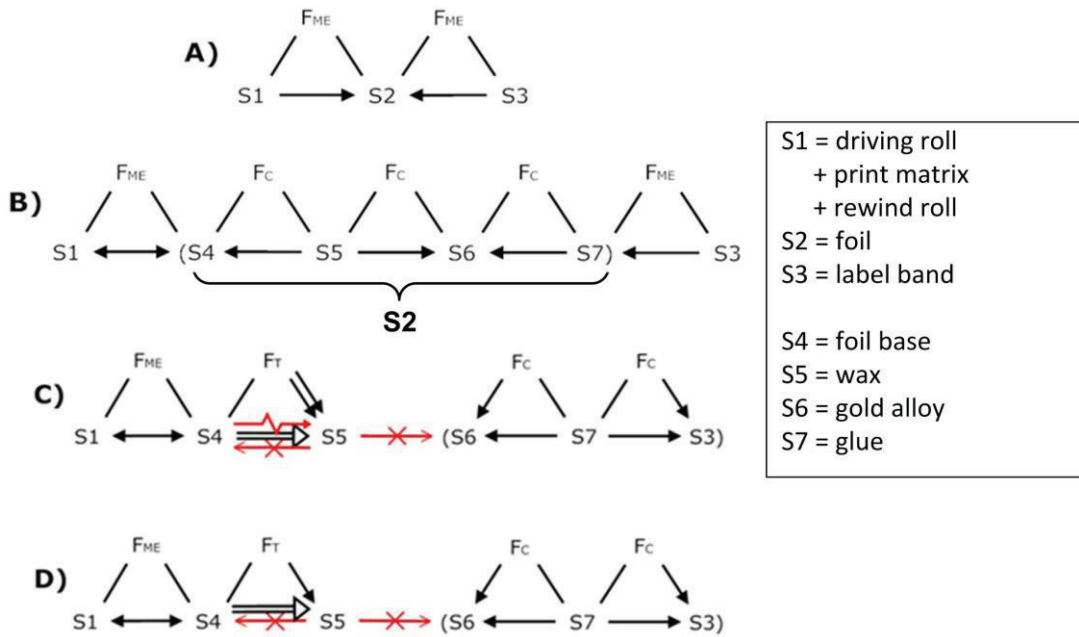


Figure 4: Su-Field diagram of the embossing printing process at different levels of detail.


Regarding the use of the Trends of Evolution, as suggested by the classification generated in the previous paragraphs for the design solution search, they allowed identifying the actual level of the system evolution and they suggested future developments which have been integrated in the proposed design solution as described in the following.


Solution phase

During the solution phase, the Inventive Principles have been applied by means of the Contradiction Matrix [12] for solving the system conflicts, aiming at generating redesign solutions. Some of them are reported in figure 5. For example, the improving feature “Loss of substance”, connected to the foil material waste, is put into relationship with the worsening feature “Stress or Pressure”. In this case, the suggested principles are: 3, 36, 37, and 10.

Focusing on the search of design solutions, the 76 Standard Solutions method suggested some hints about open issues remaining after the proposal of the main solutions. Figure 6 qualitatively shows the algorithm as applied in the field.

Interactive TRIZ Contradiction Matrix:

23: Loss of substance 

11: Stress or pressure 

Tip: Select the features then click on the TRIZ lookup button

The TRIZ Matrix proposes the following Principles to solve this contradiction:

Improving 23: Loss of substance without damaging 11: Stress or pressure

<p>3. Local quality</p> <ul style="list-style-type: none"> • Change an object's structure from uniform to non-uniform, change an external environment (or external influence) from uniform to non-uniform. • Make each part of an object function in conditions most suitable for its operation. • Make each part of an object fulfill a different and useful function.
<p>36. Phase transitions</p> <ul style="list-style-type: none"> • Use phenomena occurring during phase transitions (e.g. volume changes, loss or absorption of heat, etc.).
<p>37. Thermal expansion</p> <ul style="list-style-type: none"> • Use thermal expansion (or contraction) of materials. • If thermal expansion is being used, use multiple materials with different coefficients of thermal expansion.
<p>10. Preliminary action</p> <ul style="list-style-type: none"> • Perform, before it is needed, the required change of an object (either fully or partially). • Pre-arrange objects such that they can come into action from the most convenient place and without losing time for their delivery.

Figure 5: Some solutions proposed by the Contradiction Matrix [12].

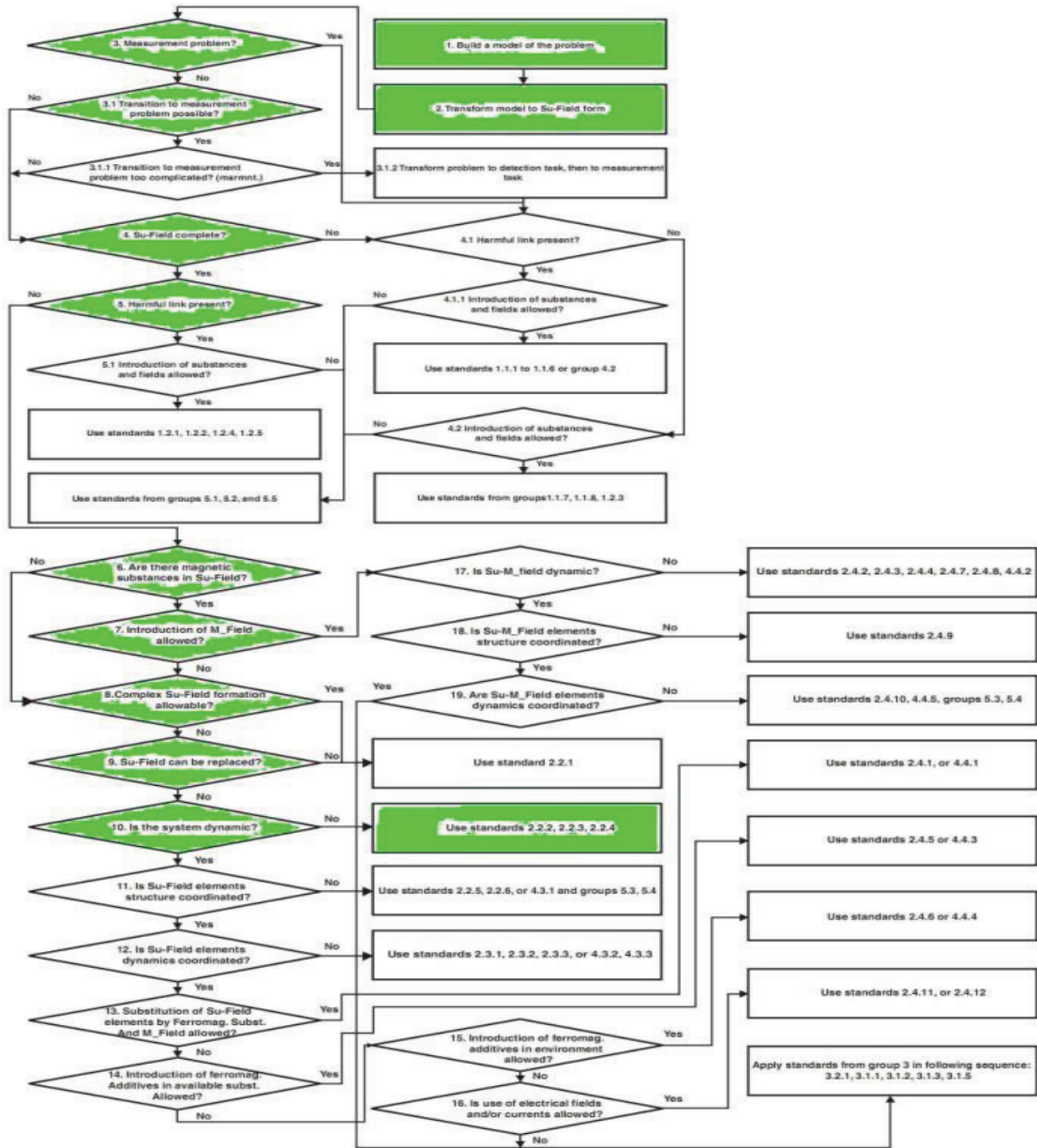


Figure 6: The 76 Standard Solutions algorithm application to the printing process problem.

Results

This case study has been conducted searching for both redesign and design solutions regarding the printing process. In the redesign case, the problem solving procedure has been conducted using the TRIZ methods FA, RCA+ and RelEvent Analysis, and it generated two possible solutions: one proposes the substitution of the foil with a tank of gold alloy powder; the other suggests the transport and printing of this material by means of an electrostatic field. Regarding the search of design solutions, the problem solving process considered the use of the Trends of Evolution, Su-Field analysis and of the 76 Standard Solutions. Also in this case, two different solutions for a complete new design of the system have been generated. Both of them suggest, in different ways, the adoption of a magnetic field and of a heating system to position and fuse the gold alloy powder.

The Sei Laser Converting srl evaluated the solutions to check if they can be really tagged as design or redesign ones. The results of this evaluation confirmed that the classification is correct; thus it can be used as a helpful tool in deciding if, when, and how to adopt the TRIZ methods to solve problems.

5. Discussion

The main purpose of the classification of the TRIZ methods proposed in the first part of this research is to speed up the application of them. Moreover, this classification wants to be a tool to suggest and help the choice of the most suitable TRIZ methods given the desired level of involvement of the SMEs, in terms of time, costs and resources. The proposed classification, reported in table 1, has been applied to a case study concerning a printing problem. As a result, the application of the TRIZ methods during the three different TRIZ problem solving phases, given the type of solutions suggested by the classification, generated the following considerations.

The use of the IC and the RC allowed a fast and clear definition of the system and process without requiring the constant presence of the company technicians during the investigation phase. These two methods may be used for the starting steps of both redesign and design solving processes.

The use of abstraction phase methods as FA, RCA+, RelEvent Analysis and SU-Field Analysis confirmed the great potential of these methods for the identification of the system components and super-systems and for the identification of their problems and conflicts, all of this, once again, classified by the solution type (design VS redesign).

Finally, the use of the Trends of Evolution allowed a more general vision of the future developments of the system/process. Moreover, it enlarged the landscape of solutions making this method the perfect tool for the generation of design solutions.

6. Conclusions and future work

One of the goals of this project was to classifying and subdividing the TRIZ methods in order to foresee the generation of solutions falling into different categories. The main criterion to define these categories is the type of adoption of the found solution concepts. These concepts may differ by the level of innovation and system changes that a company wants to obtain. Thus it is possible to distinguish redesign and design solutions.

Then the proposed classification has been tested and validated by means of a case study concerning a printing problem. This investigation in the field confirmed that the application of different TRIZ methods during the problem solving process conducts to the different solution approaches as expected.

These differences and their formalization represent an important information and an important decisional degree of freedom for the SMEs that would need and like to adopt TRIZ but that, up to now, have not because of a scarce, poorly-organized knowledge about it.

Another important consideration, highlighted by this research, is that design solutions usually need more resources and additional trials and this implies a slowdown in the ROI due to the time of development and realization of the proposed solutions. For these reasons it would be suitable to use some fastening techniques during the research and development processes, perhaps by revisiting these methods and techniques from a TRIZ point of view.

In the future, the authors will set up the proposed classification by the investigation of other TRIZ methods and the development of other case studies in order to create an effective tool for the application of the TRIZ theory in SMEs.

7. Summary

This paper proposes a classification of TRIZ methods based on the adoption of the found solution concepts in the system under analysis. This classification is intended as a tool to foresee the generation of solutions falling into two different categories: redesign and design solutions. The results of this research have been applied in the field thanks to the collaboration with a hi-tech SME, the Sei Laser Converting srl a part of Sei Laser group.

In particular a digital converting and finishing systems has been studied, investigating on a laser printing problem. The analysis of the problem was subdivided in the three proposed phases: Investigation, abstraction and solution. This procedure has generated two different levels of solution, one about a completely new design and one about the redesign of a printing system component. The results, validated by the Sei Laser Converting, confirm that the proposed approach represents a strategic tool for TRIZ adoption in SMEs and a valid mean for reaching innovation.

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