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A WATER SAVING SOLUTION WITH A TRIZ BASED METHOD

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Abstract

The number and breadth of eco-improvement methods has been steadily rising over the past decades. However a lot of eco-friendly product are struggling to find their collocation on the market. This deficit is generally due to the high costs of the proposed solutions.
TRIZ methodology offers a structured way to simplify a technical system, exploiting all resources within it and overcoming internal contradictions that could prevent his evolution. Unfortunately a complete TRIZ activity could be time-consuming and requires people skilled in the art.
In the present paper, we propose a simplified scheme, conceived to facilitate the use of the resources, totally based on TRIZ. Not to substitute, but to get along and systematize eco-design.
A case study is proposed to save water from the tap opening until hot water starts to flow, which is usually wasted. Starting from an Italian application (www.bluewatersaving.it) obtained through patent research, the method can make this solution cheaper and more robust. Considering that for a big house (120 m2, 4 people) the water saving is up to 120k litres per year, the benefit consequential to its adoption on the planet would be considerable.

Keywords: Sustainability, TRIZ, Ecodesign, Design methods

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1 INTRODUCTION

What do the terms "Design for Life", "Design for Environment", "Sustainable design" mean? Many authors have expressed about. According to McLennan (2004), a sensitive design must eliminate completely negative environmental impact.
During the years, to achieve these aims, several approaches have been developed and commonly called eco-design methods. Generally, the methods propose a series of guidelines to reduce the environmental impact through the re-consideration of some topics, like material, waste, emission, packaging, transport, etc., during the entire product life cycle.
These approaches have been stable introduced in every day design process, leading to a great number of products and systems; however, only a restrict number or them has become part of everyday life. This because, like explained by Quella and Schmidt (2003), not only to perform the functionality and respect the environment alone can be insufficient, but social acceptance and competition have also to be considered for the success of a product. For this reason, the constructive simplicity and low costs are crucial factors to develop a sustainable innovation that is struggling to take off.
The problem solving methods may help in this way and in particular TRIZ method (Altshuller, 1999), a theory for inventive problem solving, developed by Althsuller and its collaborators, starting from the forties, screening tens of thousands patents in Soviet Union with the aim to find a restrict number of common inventive principle to innovate. TRIZ may help in problem solving because it provides a complete systematic path that guides and support each phase of problem solving activity. TRIZ has numerous previous integrations with eco-design (i.e. Jones et al., 2001; Chang and Chen, 2004; Russo et al, 2014), successfully achieving the goals of eco-design but ever able to concretely work on social acceptance and competition.
However, we believe that the same TRIZ may works also to guarantee the last two aspects, thanks to its attitude to work with a high degree of abstraction, continuously leading the designer to consider the concept of ideality. This is translated not only into energy consumption minimization but also into the reduction of number of the components and of the costs, due to a better utilization of the resources in the system.
In this paper, we propose a TRIZ-based approach to design for sustainable life that allows to simplify the eco-improved devices in the market, reducing the costs and increasing the diffusion, without compromising the present advantages. The proposed integration with TRIZ method for eco-design does not want to substitute but to provide a systematic approach to it. In addition, we propose a method to manage the TRIZ tools of IFR and resources, currently missing, also with the aim to simplify list in part the difficulties of TRIZ for non-expert designers.
A case study about a system for sanitary water recirculation destined to domestic use is proposed to explain the proposed approach.
A specific patent class, F24D17/0078, is focused on hot water supply systems with water recirculation devices. Most of the patents allow to save the water that is wasted from the moment that opens the faucet until it begins to leave the hot water. A deep patent analysis has been conducted in order to identify the most interesting invention already present in the patent database. This will be the starting point to apply the proposed TRIz based methodology.
The structure of the paper is as follow. Section 2 presents a state of the art about TRIZ theory, the concept of ideality and the resources; section 3 contains the proposed approach to manage the resources; in section 4 is presented the case study and section 5 draws the conclusions.

2 STATE OF THE ART OF TRIZ THEORY

Developed by Altshuller since the second half of the forties, TRIZ theory want to extract and map a common resolutive path, by analysing a large number of patents. The first official publication about TRIZ dates back to 1956 (Altshuller and Shapiro, 1956); in which the authors outline, albeit in an early form, some of the most well-known tools of the theory, such as technical contradictions, concept of ideality, multiscreen and inventive principles.
Over the years, the tools have been refined with the contradiction matrix (1964), ARIZ (Altshuller, 1963), an algorithm that map TRIZ theory and its tools in a sequential manner, and the introduction of the standard solutions (Altshuller, 1985). The physical contradictions (Zlotin et al., 1977) represent a turning point in the method and they were preferred by Altshuller compared to the administrative and technical contradictions due to the increased resolutive strength. Recent developments of the

methodology include various re-updating of the contradiction matrix (Mann, 2003) and OTSM-TRIZ (Cavallucci and Khomenko, 2007). TRIZ theory can be generally summarized in three steps:

- General problem formulation: starting from a specific problem, you gather all the information and you reformulate it in an abstract way, using some of the tools of the theory (top model or small model, ENV model (Cavallucci and Khomenko, 2007), ideal final result (Altshuller, 1984). The final reformulation is in terms of contradictions or a kind of functional analysis called Su-Field model (Altshuller, 1984).
- Concept/General solution definition: Contradictions and other problem models can be translated into conceptual solutions by means of TRIZ techniques (ARIZ, separation principles, contradiction matrix, 40 inventive principles, 76 standard solutions). In this way, the designer can work with a finite number of general suggestions.
- Specific solutions definition: the designer must translate the conceptual identikit of a solution into a real and working solution by using resources already present in the product itself or in its environment.

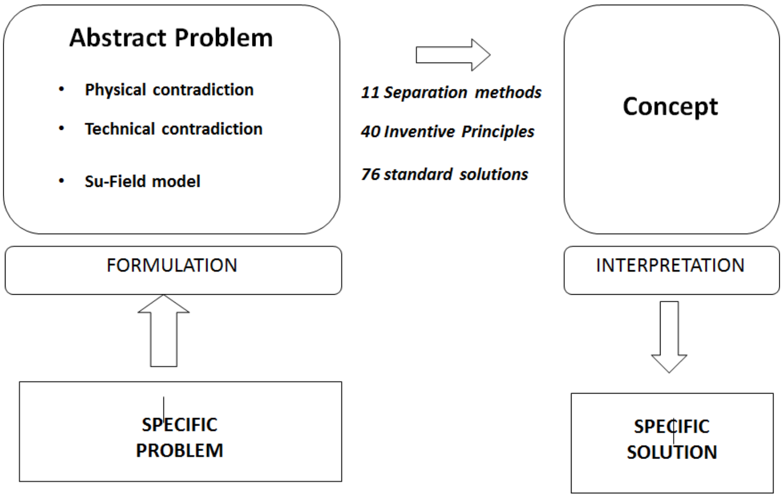

Figure 1. TRIZ overview

2.1 TRIZ and design for life and environment

TRIZ was a lot applied to sustainable design, in various way: to reduce pollution (i.e. Yang and Chen; 2012; Sheng and Kok-Soo, 2010), to reduce energy consumption (i.e. Jones et al., 2001) and in general for eco-design related themes (i.e. Chang and Chen, 2004; Yeh et al., 2011). The method is used both alone and integrated with other methods like Eco-design guidelines, Theory of Constraints, Life Cycle Analysis and Quality Function Deployment.

2.2 The concept of ideality

TRIZ theory measure the degree of ideality of a device through the following relations (see Altshuller, 1988):

$$\textbf{Ideality} = \frac{\sum \textbf{Useful functions and benefits}}{\sum \textbf{Costs} \cdot \sum \textbf{Harmful functions}} \quad (1)$$

Where the ideality is proportional to the benefits achieved by the device and opposite to the costs and the potential or real harms of the device. This expression of ideality can be used as a measure of the achieved results of the device and to map its development, for example on the S-curve.

The evolution of a typical device toward a high degree of ideality is typically seen in the direction of:

1. Increasing useful functions and benefits;
2. Decreasing harmful functions;
3. Decreasing costs.

Ideal Final Result works on the following four features to increase the degree of ideality according to the three mentioned directions:

- Removes original disadvantage(s)
- Preserves original advantage(s)

- Does not introduce new disadvantage(s)
- Minimizes (any) increase(s) in complexity

2.3 Resources

TRIZ theory, more is strongly focused in each step on the maximum use of the available resources or all that is internal or external to the considered technical system, which is not exploited to its full potential. The research on these resources reveals new opportunities to ameliorate the device. In particular, between them, also the negative elements like heat to dispose, wastes, resonance phenomena, etc., can be useful to solve the problems. Nowadays there are several database of resources (Altshuller, 1999), which often mostly differ between them but can be divided into the following categories:

- Materials: waste, economic materials, substance flows, features of the substances;
- Fields: internal energy, energy close to the device, potential fields, energy derived from waste;
- Time: anticipate an action, periodically repeat an action, work in parallel, work in different periods;
- Functions: the resources provided by the same functions, the negative functions;
- Space: empty spaces, other dimensions, alignments, symmetries, nesting;
- Information: provided by the substance, typical of the material, temporary, about a change of state.

3 PROPOSAL

Comparing the three proposed directions to increase ideality and the four proposed features, we find that they are generally already reachable from traditional design methods. To increase benefits for example can be achieved through the enhancement of product functionalities, in terms of introducing new functions or improving the existent functions, and increase the product sustainability by reducing environmental impact. In literature, several approaches can be used to achieve these aims, between them function based methods like the Systematic Approach of Pahl and Beitz (Pahl and Beitz, 1977) and Function Behaviour Structure theory (Gero, 1990) to increase product functionalities and eco-improvement methods, like Ten Golden Rules (Luttropp, 2006) and ECOPILOT (Wimmer, 1999) to increase product sustainability.

Decreasing harms can instead be achieved through risk analyses methods like Fault Tree Analysis and Failure Modes and Effects Analysis (Stamatis, 2003).

Decreasing costs can instead be achieved through improving the product realization and through product simplification (Rihtarsic et al., 2012); but, if the first one is generally covered by the design for manufacturing and for assembly methods, the second one do not have a reference theory within traditional approaches.

To simplify these products in order to guarantee an effective development in the market, we propose the use of TRIZ theory and in particular resources table and physical contradictions tools, to simplify the products used in combination with the best-known theories to achieve the other goals.

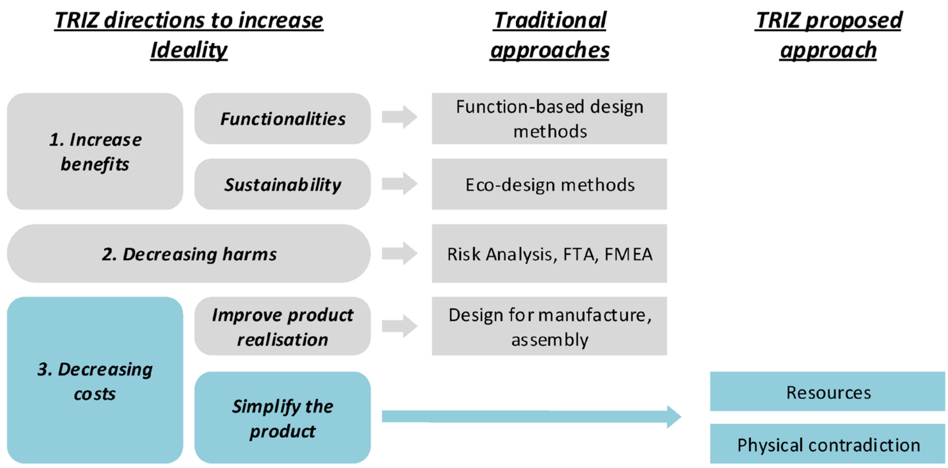

Figure 2. Overview about methods to increase the product ideality

3.1 Proposed use of the resources

Reaching the Ideal Final Result or the maximum degree of ideality is impossible, however it can be approached using the resources, present inside and outside the device. Between them, we have an important list of physical effect and structural properties collected during the years by TRIZ researchers. But if on one hand, these set is complete on the other hand it can be difficult to consult. During the years, several approaches have been developed to increase the efficiency of its use; one of them is the pointers to effects (i.e. Salamatov, 1999). The problem with these tools is that they are already too abstract and ambiguous, limiting most of the time only to generic indication on how to achieve the determined function in a behavioural level or at a too abstract structural level (i.e. structural properties), without specifying how to modify/replace in practice the components of the device. For these reasons, we have developed a series of guidelines to better utilize the resources, centered on the device that in our case is a product with certain functions, eco-friendly and sufficiently secure but with a low market appeal for its high costs. Thus, in our specific case we want to reduce only the device complexity in order to increase the last aspects.
To better organize the use of the resources we have developed the following table of guidelines.
First of all it has yet to be selected the component of the system that we want simplify and then we have to apply them to it. This procedure can be applied iteratively also to all the other components.

Table 1. The proposed approach to manage the resources

<table>
<tr><th colspan="2"></th><th>Maintain the component?</th><th>Strategies</th></tr>
<tr><td rowspan="4">Use resources inside the device to perform the function of the component</td><td rowspan="2">Use the resources of the component</td><td rowspan="2">Yes</td><td>1. Use better the utilized resources of the components</td></tr>
<tr><td>2. Use unutilized resources of the components</td></tr>
<tr><td rowspan="2">Use the resources of other components</td><td>Yes</td><td>3. Use only a part of the component and eliminate the rest</td></tr>
<tr><td>No</td><td>4. Eliminate the component</td></tr>
<tr><td rowspan="4">Use external resources to perform the function of the component</td><td rowspan="2">Use the resources of component external to the device</td><td>Yes</td><td>5. Use only a part of the component and eliminate the rest</td></tr>
<tr><td>No</td><td>6. Substitute the component with a cheaper alternative</td></tr>
<tr><td rowspan="2">Use the resources of the environment</td><td>Yes</td><td>7. Use only a part of the component and eliminate the rest</td></tr>
<tr><td>No</td><td>8. Use entirely the resources of the environment</td></tr>
</table>

In this manner, we can search in the list of the resources with an increased comprehension about the strategy to modify the device, pooling the correspondent list of possible resources that can be useful for each strategy. From them, it can be derived a list of possible resolutive directions to be taken in order to solve the problem. The evaluation of the directions is not discussed in this paper.
The explained approach is useful at its full potential when is applied on a single component. In this manner, we can comprehend how to modify it, which other components inside or outside the device can be used, etc. However, through this approach we can encounter the following problems.

- Most obvious, when the device is simplified through one of its components in order to reduce costs, we must not lose the benefits and the degree of security, acquired through the previous steps.
- Sometimes, the selected resources of a component, already engaged in performing its functions, cannot been used by the same component to perform a function of another one to remove.

To solve these problems, we can use the TRIZ tool of contradictions.

3.2 Contradictions

Firstly the problem can be easily reformulated in the form of a physical contradiction: we want in fact simplify the system in order to reduce its costs (Evaluation parameter 1) without compromising the benefits and the degree of security previously achieved (Evaluation parameter 2). Acting on a proper parameter (Control parameter) of a selected resource, we can move from the realization of the first evaluation parameter to the realization of the second evaluation parameter.
Solving the contradiction, in this case means to find which configuration of the resource parameter leads to the realization of both the evaluation parameters, allowing to reduce the costs of the device without compromising its benefits and degree of security.

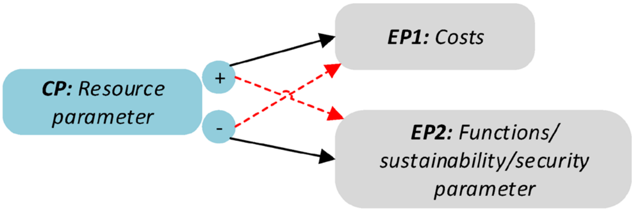

Figure 3. TRIZ contradiction: costs vs functionality/sustainability/safety

The second problem can also be formulated in a contradiction form. In this case the goal is that the considered component realizes a new function (Evaluation parameter 1), without losing its own function (Evaluation parameter 2). In this case a certain a parameter of a certain resource (Control parameter), can lead, if opportunely set, from the realization of the first evaluation parameter to the realization of the second. Solving the contradiction in this case means to find which configuration of the control parameter leads to the realization of both the evaluation parameters, allowing the device to realize a new function without losing its own function.

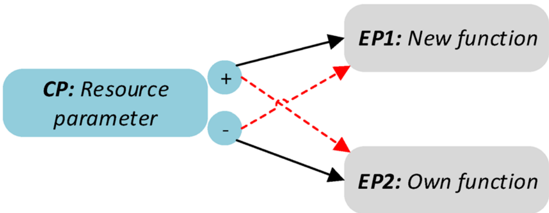

Figure 4. TRIZ contradiction: new functionality vs old functionality

Regard to the mechanism to solve the proposed contradiction, TRIZ theory suggest to individuate and opportunely segment the operative zone and operative time, as prescribed by the separation principles and by the inventive principles or following the standard solutions. To choose the right principle, a potential user may use the first three separation principles (space, time, condition) as a filter like prescribed by TRIZ theory.

4 CASE STUDY

Nowadays water saving is more than ever a felt problem as testified by the numerous patented products and plants also available on the market, especially in hotel industry. The field of application of our example is instead domestic, where the users requirements for a plant are considerable resized. For this reason, the current plants configuration for hotel industries has to be reviewed considering how the new field of application changes the requirements. For this reason our goal is not to improve the water saving rather to simplify the plant by reducing the costs.
The aim of the case study is to present how the proposed approach can help TRIZ to manage the resources to reach the IFR and how by following this approach, eco-design can be partly systematized.
The choice of starting with an existing patent to improve rather than an embodiment of the functionalities by delineating dedicated structured is part of TRIZ mentality that typically proposes the confrontation between an existing structure and an alternate configuration and provides the tools to overcome the contradiction.
However, we must confront with a series of problems that emerge by following this strategy. In the present section, our goal is to review the above concepts in detail, by proposing how the explained

approach and TRIZ may support a patent application about a plant for hot water circulation submitted in 2014 to the Italian patent office (Pesavento et al., 2014).
The goal of the proposed plant is to conserve inside the circuit the water, until it becomes hot, instead of wasting it.

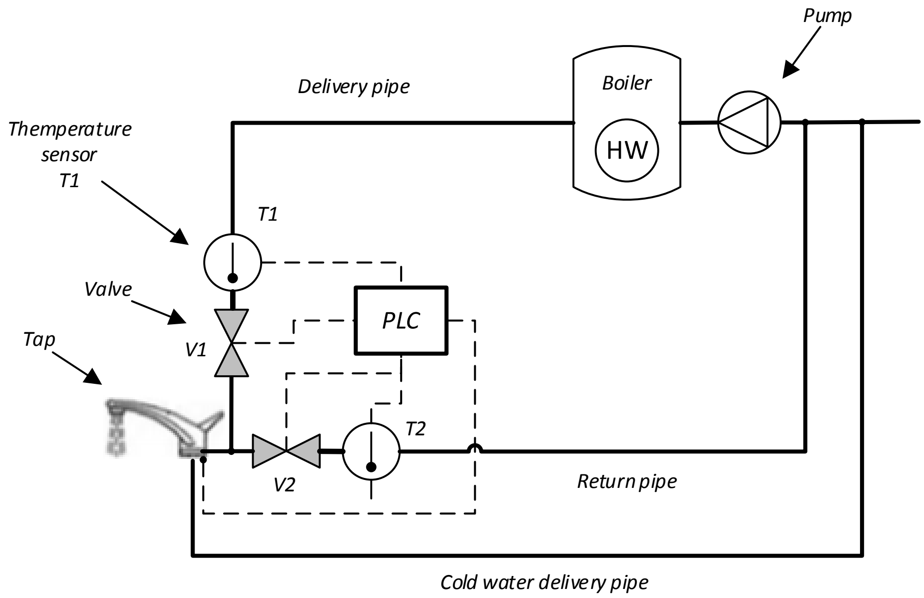

Figure 5. The water saving plant, italian patent application GE2014R000062 (Pesavento et al., 2014)

The scheme of the plant is simple, constituted by a limited number of economic components and easily implementable in residential building, especially the dated one. The advantages of this solution in term of water savings are multiple and diverse being influenced by multiple parameters explained in the following:

- The savings increase for big houses, even though the major installation plant costs, because of the more long times of water heating due to the major distances between the utilities and the boiler.
- The savings grow then proportionally with the number of inhabitants and the number of daily usages.
- The country and its water taxation also affect the savings determination, especially in contest where the water is scarce or in countries (like north Europe area) where the water taxation is high to sensitize to the public opinion to the moral problem of water consumption.

We resume in the following table the results of an analysis for three typical geographical scenarios in EU. The results are based on the water average price (€/liter) for each country (source: Il Sole 24 Ore).

Table 2. Yearly savings in different national scenarios

House dimension	Number of inhabitants (6 daily usage per person)	Annual water savings (kLitres)	Country (€/year)		
			Italy	Germany	Sweden
Big house (120 m2)	8	240000	800	1000	1200
	4	120000	400	500	600
Small house (80 m2)	6	115000	440	600	700
	3	58000	220	300	350

The guaranteed water savings can be considerable, especially for a massive application (i.e. a city). Even though the multiple advantages, this system can already be improved, simplifying the structure in order to make it cheaper and more implementable in residential building.

4.1 Plant simplification through the proposed approach

The plant is constituted by the following components: a tap, two electro valve (V1 and V2), two temperature sensors (T1 and T2), a programmable logic computer PLC, a delivery pipe, a return pipe, a cold water delivery pipe, a pump and the boiler.

The functioning of the plant in extreme synthesis is as follow. The cold water from the distribution network passes through the boiler in the delivery plant, then proceeds to the tap. If its temperature (measured by the temperature sensor T1) near the tap is cold, the PLC open valve V2 (valve V1 is already open) and the water passes through the return pipe returning to the boiler instead of flowing cold by the tap. The water continues to cycle in the circuit (delivery pipe + return pipe) until the temperature T2 is close to T1. Then the PLC close the valve V1 so that cold water from the network pass through the return pipe, pushing the hot water in the return pipe outside it. When the cold water front reaches the temperature sensor T2, the PLC close V2 and open V1. From now on, the plant works in regime as a traditional plant, with the hot water flowing by the tap.

The plant works very well, fully achieving its functionalities and guaranteeing the sustainability and the degree of safety. However, some structural modifications can be proposed in order to reduce the realization costs, making the product more desirable.

In this case study, we show how we can simplify this circuit by using the proposed approach. To do so, we analyze one by one the most important components of the system (column 1), proposing for each of them the followed strategy (column 2) between the proposals in table 1, the involved other components to simplify the system (column 3) and the relate involved resources (column 4). The possible resolutive directions are summarized in column 5.

The solutions have been generated in a brainstorming session based on the proposed strategies applied to all the components. All the strategies has been used but in the following table we propose only the most significant and innovative ways to simplify the system. The choice has been directly done with the applicant, by considering the operative needs of the product. The discarded strategies are already widely patented and applied on similar products.

Table 3. Used strategies and solutions

Component to simplify	**Strategy number**	**Considered entity2**	**Involved resources of the entity2**	**Solutions**
Recirculation pump	3. Use only a part of the component and eliminate the rest	Hot water	Gravity forces	a) Use a tank to storage water and a vertically plant and substitute a pump with a less power one, used only to lift the water to the tank
Boiler	6. Substitute the component with a cheaper alternative	Temperature sensor T1		b) Use the external temperature signal in order to activate the boiler. If T1 measure hot water, for sure also inside the boiler the water is hot.
Delivery Pipe	7. Use only a part of the component and eliminate the rest	Delivery pipe	Solar radiation	c) Elongate the tube to go external and use the solar radiation to help the warming recirculating phase
			Walls insulation	d) Use the insulation provided by the walls insulation in order to diminish the thermal losses
	1. Use better the utilized resources of the components	Tube length and curves	Gravity forces	e) Make the whole circuit smaller through accurate research of the circuit design
Delivery pipe/Return pipe	1. Use better the utilized resources of the components	Tube length and curves	Regeneration	f) Pipes designed with a heat exchanger to improve thermal performances

Temperature sensor 1	4. Eliminate the component	Delivery pipe	Thermal tension	g) Application of a strain gauge that measure the thermal dilatation of the delivery pipe or of an internal layer, caused by the hot water, in place of the temperature sensor T1
Temperature sensor 2	4. Eliminate the component	Return pipe	Thermal tension	h) Application of a strain gauge that measure the thermal dilatation of the return pipe or of an internal layer, caused by the hot water, in place of the temperature sensor T2
Valve 1	5. Use only a part of the component and eliminate the rest	Valve 2	Three-way valve	i) Substitution of the two valves with a single three-way valve governed by the PLC
Return pipe	4. Eliminate the component	Delivery pipe	Perforated substance	j) Coaxial delivery pipe (inside the thickness)
		Cold water delivery pipe	Space, volume	k) When the cold water is not required the cold water delivery pipe is used as return pipe

The proposed resolutive directions are actually under evaluation by the inventors of the proposed patent application to be combined with the initial invention for strengthening the innovative idea, increasing its market potential penetration. Some of the solutions in table 3 are only virtual instructions, others can just be possible solutions and still others are possible solution but only after the resolution of their possible contradictions.

4.2 Solutions development

In the following, we propose two examples for developing resolutive directions provided in table 3, which respectively regard (1) the eliminations of the valve V1 and (2) the return pipe.

Solution 1: in the actual system, two valves (V1 and V2) set the circuit. The proposed simplification regard the elimination of one of them by using the other, but in what manner V2 could ensure the functionality of V1? To do this, V2 has also to possess a third entrance in order to link the return pipe to the tap and to the delivery pipe. A common three way valve available in the market may be more than enough to perform this solution. This is an example where TRIZ is no necessary to improve this solution**.**

Solution 2: An example of the application of TRIZ methodology is instead a further modification that we can bring to the circuit concerns the return pipe. This element consists in a marked loss factor from structural design, having to replicate largely the functions of the delivery pipe of the traditional system. Following the proposed approach, we can interrogate us about the following possibilities applied to the component of return pipe.

Can we eliminate it, by using the delivery pipe both for the delivery and for the recirculation of the water inside the circuit? Built an alternative system that use only the delivery pipe surely guarantees savings but how can be possible to perform the function of the return pipe or the recirculation?

TRIZ theory may help to solve this contradiction by providing the separation principles. In this manner we can propose the following resolutive direction:

- Separation in time: not the entire operative time is spent for the recirculation of the water in the circuit. The delivery pipe can be used for the 70% of the time to provide the hot water and the remaining time to the recirculation of the cold water in the boiler, by changing the sense of water circulation.
- Separation in space: not the entire section of the delivery pipe has to be used for the delivery, but a part of it can be used also for the recirculation. To develop this solution we can use the resources: exploiting the thickness of the mandatary pipe as resource, we can perforate it and using the obtained space for the water recirculation. The most common similar product on the market is the coaxial pipe.

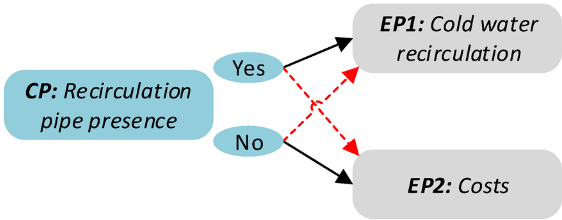

Figure 6: TRIZ contradiction

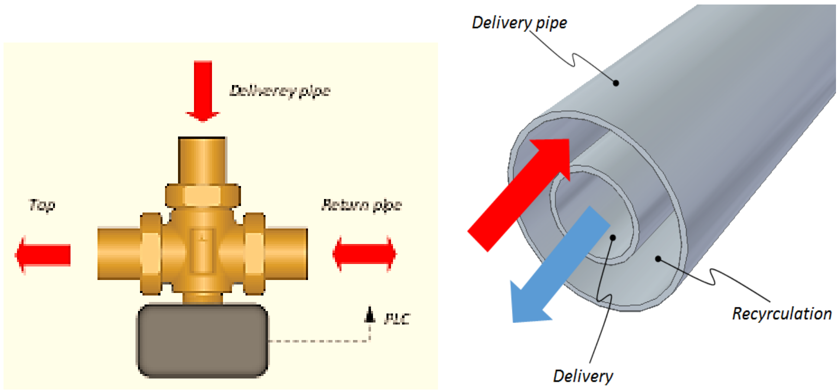

Figure 7. Three way valve and coaxial pipe

5 CONCLUSIONS

The leach of simple and systematized series of steps of Eco-Design methods to solve the presented problems has been filled by using TRIZ method that has provide a systematic step by step method. In particular the guidelines can further simplify the procedure by proposing a method to clearly manage the TRIZ available resources, currently missing, to increase the level of ideality. Through this approach, we can use the resources, with a major awareness about the involved entity and the strategies to simplify the system by using the same resources. TRIZ contradictions have been introduced to solve any problems that may occur in product simplification like the loss of their functionality, the sustainability and safety.
The real case study, selected as the most interesting solution for water saving found on patent class F24D17/0078, shows, with two examples, how to manage the resources in a more ordered manner without attempt a trial and error and highlighting how in certain cases the application of TRIZ to eco-design can solve the open contradictions to increasing the market penetration of the solution with a great benefit for the environment.

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REFERENCES

Altshuller, G.S., Shapiro, R.B., (1956) “On Psychology of Inventive Creativity”, Problems of Psychology, Vol. 6, p. 37-49.
Altshuller, G.S., (1963) “How to Work on an Invention: About a Theory of Inventiveness”. Azbuka Ratsionalizatora, Tambov (In Russian).
Altshuller, G. S. (1984). Creativity as an exact science. Gordon and Breach.
Altshuller, G.S., (1985) “Inventive Standards 76” (in Russian).
Altshuller, G. S. (1999). The innovation algorithm: TRIZ, systematic innovation and technical creativity. Technical Innovation Center, Inc.
Cavallucci, D., Khomenko, N., “From TRIZ to OTSM-TRIZ: addressing complexity challenges in inventive design”, International Journal of Product Development, 2007, p. 4-21.

Chang, H. T., & Chen, J. L. (2004). The conflict-problem-solving CAD software integrating TRIZ into eco-innovation. Advances in Engineering Software, 35(8), 553-566.
Gero, J. S. (1990). Design prototypes: a knowledge representation schema for design. AI magazine, 11(4), 26.
Jones, E., Mann, D., Harrison, D. D., & Stanton, P. N. (2001). An Eco-innovation Case Study of Domestic Dishwashing through the Application of TRIZ Tools. Creativity and Innovation Management, 10(1), 3-14.
Luttropp, C., & Lagerstedt, J. (2006). EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development.Journal of Cleaner Production, 14(15), 1396-1408.
Mann, D., DeWulf, S., “Updating the Contradiction Matrix”, TRIZCON2003: 5th Annual International Conference of Altshuller Institute for TRIZ Studies, Philadelphia, PA, USA, March 16-18, 2003.
McLennan, J. F. (2004). The philosophy of sustainable design: The future of architecture. Ecotone publishing.
Pahl, G., Beitz, W., & Feldhusen, J. (1977). Konstruktionslehre (Vol. 7). Berlin: Springer.
Pesavento, E., Pesavento. F., Pesavento, L. (2014) Impianto per l'erogazione di acqua calda con risparmio idrico ed energetico (System for hot water delivery with water and energy savings), Italy GE2014R000062.
Quella, F., & Schmidt, W. P. (2003). Integrating environmental aspects into product design and development the new ISO TR 14062. The International Journal of Life Cycle Assessment, 8(2), 113-114.
Rihtaršič, J., Žavbi, R., & Duhovnik, J. (2012). Application of wirk elements for the synthesis of alternative conceptual solutions. Research in Engineering Design, 23(3), 219-234.
Russo, D; Rizzi, C; Monteliscinai, G. (2014) Inventive guidelines for a TRIZ-based eco-design matrix. Journal of Cleaner Production, 76: 95-105.
Salamatov, Y. (1999). TRIZ: the right solution at the right time: a guide to innovative problem solving.
Sheng, I. L., & Kok-Soo, T. (2010). Eco-efficient product design using theory of inventive problem solving (TRIZ) principles. American Journal of Applied Sciences, 7(6), 852.
Stamatis, D. H. (2003). Failure mode and effect analysis: FMEA from theory to execution. Asq Press.
Wimmer, W., ‘Environmental Improvements of a Citruspress Using the Ecodesign Checklist
Method’, in Proceedings of the 12th International Conference on Engineering Design, München,
Germany, 1999, pp. 465-468.
Yang, C. J., & Chen, J. L. (2012). Forecasting the design of eco-products by integrating TRIZ evolution patterns with CBR and Simple LCA methods. Expert Systems with Applications, 39(3), 2884-2892.
Yeh, C. H., Huang, J. C., & Yu, C. K. (2011). Integration of four-phase QFD and TRIZ in product R&D: a notebook case study. Research in Engineering Design, 22(3), 125-141.
Zlotin, B., Litvin, S., (1977) “Creative Imagination Development”, St. Petersburg (in Russian).